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PRACTICAL TANK OPERATION

By JAMES ARRANDALE

THE subject, "Practical Tank Operation," is a broad one as there are so many different types of tanks or furnaces and also, because each tank has its own peculiar characteristics. It seems strange, but we all know it is true, that we might build two tanks in the same plant, both exactly alike in every apparent detail and yet not be able to operate both of them in exactly the same way. It is necessary, therefore, that the operation of a glass furnace should be in capable hands.

Glass tank operation, until the last few years, was sadly neglected. Thousands of dollars were spent in constructing tanks with very little thought being given to operation after they were built. The idea seemed to prevail that anyone could operate a good furnace.

Later, however, the trade started to demand a much better and more durable glass, with the result that both practical and technical men awakened to the fact that the durability of glass depended, to a great extent, upon its physical nature and that the physical nature in turn was largely dependent upon the operation of the tank.

We have a great many defects in glass which result from a variety of causes and which may make their appearance at any stage of the manufacturing process. A large number of these are termed "machine defects" while in reality, they owe their origin to faulty tank operation.

To classify all these defects and determine which might be the result of faulty tank operation would require more time than I have been allotted. For that reason, I will deal only with a few of the major defects.

Before continuing, let us check over some of the things a man in charge of a tank operation must be certain of before he can successfully operate a tank. For instance, he must be sure that the materials making up the batch are mixed correctly and that no segregation has occurred. Likewise, he must be informed when a change is made in the source of supply of any of the raw materials making up the batch.

One of the most important items to the man in charge of tank operation is the uniformity in quality of the fuel supply. If natural gas is being used, there is not much danger of its changing in quality. If oil is being used, he must watch the gravity and viscosity of the oil very closely and must also be notified of any change in the source of supply. If the fuel is air, steam, gas, or what is generally known as "producer gas," he must maintain a sharp watch for any change in the quality of same. I cannot help stressing this point as I am convinced that a great deal of the so called "bad glass" drawn from a continuously operated tank which is fired with producer gas, is a result of a change in the nature of the gas. In this event, let me say that the man in charge of tank operation ought to make a thorough study of the Gas Producer operation.

I do not wish to create the impression that the man in charge of tank operation must be a combustion engineer, but I do wish to stress the importance of his thoroughly understanding the effect of combustion upon the glass that he is melting. With the increased demand for a better and more durable glass and the present day necessity of efficient operation of the whole plant, we cannot help emphasizing the necessity of the fuel being of the very best quality.

Glass itself may be said to be a compromise, sacrifice being made very often in one direction in order that perfection may be achieved in another. One manufacturer may be compelled to sacrifice a little transparency in order to achieve another more desirable quality. Chemical ware, for example, is noted for its high durability and resistance to thermal shock. The very high viscosity of a glass of this type, however, makes it necessary to sacrifice other desirable qualities, such as workability and homogeneity, or freedom from cords. In addition, the high temperatures necessary for this type of glass cause excessive wear on the tank blocks.

In the following discussion I will confine myself to a common soda-lime-silica glass, with the exception that I will add a little feldspar since a great many firms use this material as an addition to the batch. I will also use for my discussion a regenerative side-port furnace, continuously operated and fired with producer gas. Nevertheless, I think we all agree that regardless of whether the furnace is side-port, end-port or recuperative, or whether it is fired with natural gas, producer gas or oil, the effects of combustion and operating temperature on the glass are very much the same and any or all types will produce bad glass of one kind or another unless watched closely.

Among the major defects in a soda-lime glass (and probably the one responsible directly or indirectly for the greatest loss in production) is heterogeneous glass, otherwise known as cordy glass. The production of a commercially homogeneous glass in a continuously operated tank is not as simple as it may seem and because of the demand for a more durable product, what we considered practical tank operation a few years ago we might consider as very impractical today.

When the batch is fed into the tank at the "doghouse" and is melted, it becomes a glassy, transparent mass which is formed by the inter-reaction of various chemical compounds at high temperatures. This inter-reaction results in the formation of new compounds which, at this high temperature of formation are soluble in each other. The molten liquids produced by the inter-reactions of the various compounds are not in the form of a homogeneous solution but tend to run in streams or layers, forming what we know as "cordy glass." These streams or layers must be mixed or stirred together to form a homogeneous mass. This is accomplished in two ways, first by the evolution of gas from the batch during melting and second by convection. The evolution of gas from the batch during melting serves to effect a mixing of the molten glass. The speed at which this gas is released will, of course, determine the extent of the mixing. If the temperatures are low, the gas will be released slowly and the melting will be sluggish because of the correspondingly high viscosity. On the other hand, if the temperatures are high, the gas will be released with a vigorous action as a result of the decreased viscosity of the molten glass. This vigorous agitation or boiling action serves to stir or mix these various solutions.

Here we see the advantage of uniform temperatures, sufficiently high to secure the much desired agitation in the early stages of melting. If, however, the temperature over the whole melting area is not uniform and hot spots have been allowed to develop, it is evident that there are areas which are more heterogeneous than others, or in plain glass house language, more cordy than others. Then, there is only one way in which this essential mixing of the molten glass can be accomplished and that is by the second method or convection currents which tend to keep the glass moving, thereby producing a mixing action. If this fails, the finished product will be very much reduced in quality, for if any great amount of non-uniform glass remains in the melt when it reaches the bridge wall of a continuously operated tank, the possibility of its being mixed together before reaching the machine is very slight. There are men who do not agree with this last statement but be that as it may, this has been our experience not once, but many times.

Some will tell us that "cords" are not formed in the melter but have their origin in the refiner or working end of the tank. They are right to a certain extent but the lines or streaks visible to the eye in the finished ware are not the same cords as are formed during the melting process. Cords that originate in the refiner or forehearth are caused by two or more glasses whose natures differ in temperature only. This sort of cordy glass will anneal perfectly. These are not the cords that cause the ware to break in the thermal test and do not show colored streaks when viewed in the polariscope.

Of course, it is a well known fact that all glasses drawn from a continuously operated tank are slightly heterogeneous, if inspected with a microscope or with a sensitive polariscope. However, very faint cords do not affect the laboratory tests and, therefore, the glass is considered to be of commercial quality.

Seeds and blisters constitute defects probably next in importance. For our purpose, I shall consider both of these defects as one because they originate from the same source. As stated previously, the melting process liberates large volumes of gases as a result of the various chemical reactions, and although the bulk of the gases escapes from the melt, a considerable portion remains because of its inability to penetrate the viscous mass. The second or refining stage has for its object the complete removal of these seeds and blisters in order to leave a clear solution ready for working.

It is evident that the temperature in the melting zone, because of the addition of fresh batch material, will be lowered somewhat but will again rise until it reaches the desired melting temperature. This high temperature should continue into the refining area, far enough to eliminate all the remaining bubbles. This is a very important stage of a successful tank operation, for if any great amount of the remaining gas goes into the solution, it is very apt to reappear while the glass is being worked.

Because of the great heat loss from a glass tank through radiation, it is perfectly natural that there should be a desire to save fuel and to melt glass with the lowest possible amount of fuel per pound of glass. It is common practice, when figuring the efficiency of glass tanks, to consider the amount of glass produced against the amount of fuel consumed. From this, it would appear that "Practical Tank Operation" would be the production of glass with the lowest possible consumption of fuel per ton of glass produced. Tank operation, from this standpoint, might show a very high efficiency in fuel consumption and at the same time, a very low efficiency in the production of a marketable product.

Suppose it is our desire to get fuel economy and we are attempting to get every bit of heat value from the fuel, or as near 100% combustion as possible. Since I am using producer gas for this illustration, we will assume that under ideal conditions the producer is consuming 20% of the total heat value of the coal in the production of gas. This would mean that we still have 80% of the total heat value left in the gas. We assume that through good insulation of the gas leads, we are able to preserve the sensible heat in the gas when it leaves the producer and that we have ample checker capacity for the preheating of both gas and air; also that the tank has ample stack draft, making it possible to produce a temperature well above the highest temperature required. In other words, everything is in "tip-top" condition for a very efficient operation of the tank. Since fuel economy is our desire, it is necessary that the tank man use all the air possible in the combustion so that when the burnt gases leave the tank, they do not contain any combustible matter. This means that we are on the oxidizing side of the neutral fire.

With a side-port tank, it is evident that with this sort of firing, the last few feet just before the burnt gases enter the exhaust ports, will have to be heated almost entirely by radiation as the flame will taper off and completely burn out four to five feet from the wall. If at times the quality of the producer gas should change slightly, the flame, if watched closely, may taper off from six to seven feet from the wall. Because of the great amount of non-combustible gases which have accumulated in the fire from the producer gas and the excess air, it is possible that the outgoing gases have started absorbing heat from the glass and brick work. Thus, we have

a slight dropping of the temperature on one side of the furnace. When the valves are reversed, we have a corresponding temperature drop on the other side of the furnace. With the temperature rising and falling on the sides and with the tank continuously hot in the center, we are producing glasses of a non-uniform quality. In the melting of glass the temperature plays a very important part in the physical nature of the resultant glasses. Therefore, if a radical difference exists between the temperature of the sides of the tank, compared to the temperatures of the center, the glass produced will require just that much more stirring or mixing to acquire the necessary homogeneity.

At this point I wish to say that the illustrations I am going to try to present are of a radical nature, in an effort to picture the very bad conditions. We all know that the results of certain bad tank conditions are reflected in the finished product and as these conditions are improved, we find a corresponding improvement in the quality of the finished ware. Therefore, the greater the amount of attention given to uniform tank conditions, the nearer the approach will be to the much desired perfect finished article.

In order to show the effect on the finished product, from a tank operated under a radical condition of this kind, suppose that through neglect on the part of the gas maker, or by a change to a different grade of coal, the gas changes in quality so that the fire shortens up still more. The result is that there is a very considerable difference in temperature between the glass in the center of the furnace and that in the sides. Suppose, also, that we are producing large size ware so that we have a heavy demand for glass at the working end of the tank. The pull on the tank naturally follows the lines of least resistance, therefore, the glass in the center, which is much softer or much less viscous than that near the side, will move faster than ever and we have produced what is known to glass makers as "channeling of the glass."

Under this condition, we may think we are saving fuel but in reality we are wasting it, as a tank operated in this way is utilizing a very low percentage of its actual capacity and the demand for glass at the working end must, in order to stay out of "seed", be reduced to conform with the speed at which the glass is moving through the center of the tank. This may be many times the rate at which the glass on either side moves, depending, of course, upon the extent of the "channeling."

Now in order to show what a little change in temperature will do to provoke a condition of this sort, I quote a paragraph from an article on "Glass Technology" by Dr. Samuel R. Scholes.

> "The viscosity of glass may be said to increase three-fold for each 180°F. drop in temperature in the melting range. In other words, molten glass at 2600°F. has only one third the viscosity of the same glass at 2420°F. Therefore, bubbles of gas rise through the hotter glass three times as rapidly for a given size."

It is natural, therefore, that as the "channeling" increases the "cordy" character of the glass will also increase. The glass from the center of the melter, moving forward much faster than that from the sides, continues to draw the cooler and radically different in nature glass into the hot stream and it is not long before it arrives at the bridge wall when, as I have said before, the possibility of its ever being stirred or mixed together is very slight. When the resultant glass goes through the machines and is made into the finished product, it is not long before the ware appears blotchy in the polariscope. A little later, we get very poor thermal tests, the result of which is the loss of all the ware until the trouble is corrected. If we are not aware of the source of trouble of this nature, the tendency is to start juggling, working and annealing temperatures and readjusting machine

The grinding and polishing plant of the Clearview Glass Co., Renfrew, Pa., leased to the West Penn Glass Co. seen from a 500 ft. elevation.

operating conditions, all of which will help but at the sacrifice of some other desired quality of the finished ware. As a result, we have dozens of other defects which we ordinarily call "machine defects," while in reality, they are the result of a poor melting condition. This ware must be sorted and resorted to find some of marketable quality, leading to increased costs and eventually to loss of business.

In the production of a *highly* commercial glass, there are two things of vital importance, namely, homogeneity and workability. Glass may be homogeneous to the extent that it anneals uniformly and appears free from "cord" in the polariscope but the workability of the same glass may still be poor.

In a tank with a demand for glass at the machines of say sixty to seventy percent of its actual capacity and operated with a neutral to slightly carbonizing flame which completely blankets the surface of the melting area, it is possible to melt a soda-lime glass, free from seed, at a temperature of approximately 2550 degrees. A tank operated in this way has a minimum of stagnant areas and thus the time elements between the doghouse and the bridge wall are considerably longer. Even though the melting is much slower and the agitation in the melt is much less vigorous, the glass remains in the tank long enough to become fairly uniform in nature.

Even though glass melted at this temperature looks good in the polariscope and the thermal test is good, it has poor workability and is subject to a variety of machine defects. On the larger ware it must be worked at what is considered "low working temperatures."

Now the question arises, "Just what is responsible for this poor workability in glass which seems to have such a high degree of homogeneity?" The answer lies in the melting temperatures. Glass melted at the higher temperatures has a correspondingly high working temperature and glass melted at what we consider as low temperature will have low working temperature.

This being true, try to picture in your mind a tank, as I said a moment ago, with a demand for glass at the machine of sixty to seventy percent of its actual capacity, with a melting temperature of 2550 degrees. Suppose, without a shut down, we increase the demand for glass at the machines to the full melting capacity of the tank. This would necessitate raising the melting temperature to not less than 2650° and we start producing glass which should be worked at a little higher temperature If we could keep these glasses in the tank for a sufficient length of time the difference in physical nature would correct itself, but this is impossible in a continuously operated tank. Some of the new glass will come through the machines in a comparatively short time, drawing with it the older and different natured glass.

Thus we have a period of about eighteen hours in which we are delivering to the machine operator glass which is sufficiently different in nature to cause him to juggle his forehearth temperatures, trying to accomplish the mixing which should have been done in the melting tank. The glass melted at the high temperature, being of harder nature, naturally requires slightly higher working temperatures to keep it soft enough to work. When the temperatures are increased slightly to accommodate the harder natured glass, the viscosity of the softer natured glass is so reduced that when the article is blown the distribution of the glass is very uneven. It is possible to reproduce this same condition with uneven temperatures in the working end of a tank which tend to complicate matters. The difference is that in the case of uneven temperatures, the trouble can be corrected in the forehearth with very little difficulty whereas in the case of hard and soft natured glass, the forhearth is entirely too small to accommodate any great amount of mixing of the two glasses.

As the harder natured glass increases in the flow of glass from the tank, the tendency on the part of the machine operator is toward a higher working temperature. If the amount of the harder natured glass is decreasing, the tendency is to lower temperatures. If the change is gradual and not too severe, the machine operator will have little difficulty in following it, but when sharp changes are made in the melting temperature, there is bound to be a period of time when defective ware will be considerably increased.

The difference in working temperatures of these two glasses may not be greater than 25 degrees. This, to the average individual, may sound ridiculous, but let me refer back to Dr. Scholes. He states that the viscosity of glass may be said to increase three-fold for each 180° F. drop in temperature in the melting range. He further states that at lower temperatures, glass changes still more rapidly in viscosity. Its mobility lessens at an increasing rate until, at temperatures somewhat below redness, all commercial glasses are rigid. Thus we realize that a 25°F. difference in working temperatures under some circumstances, will be a radical difference.

I do not wish to create the idea that all the machine defects can be corrected by a practical tank operation, but I do want to emphasize the importance of delivering to the machine operator, glass which has suitable workability for the highest production of the finished product.

From this standpoint it appears that "Practical Tank Operation" is the production of glass with workability sufficient for the highest possible production of the finished product with the lowest production of defects.

To produce glass with good workability one must select a melting temperature, depending upon the type of glass being melted, which will give a quick melt, thereby producing a vigorous agitation of the chemical compounds being formed. Maintain this temperature, regardless of the demand for glass at the working end of the tank. Be absolutely certain that the surface of the glass in the melting area is well blanketed with a neutral or slightly carbonizing flame. The temperature created in the regenerators by the absorption of heat from the burnt gases will cause a continuous rush of air through the regenerators which will produce a pressure in the tank. Raise the stack damper until this pressure is reduced so that the "sting-out" through the peep-holes reaches only a few inches on the outside of the tank. Be certain the fuel supply does not change in quality and you will experience little difficulty holding the temperatures constant. If, with this setting the temperature at the bridge is too high, reduce the flow of gas through the last ports on each side of the tank. Be sure that all the conditions necessary to a perfect tank operation are held as uniformly as possible.

DEPOSITION OF METALS ON GLASS IN VACUO

By H. W. LEE

STUDY of the phenomena accompanying the discharge of electricity through highly rarefied gas led to the discovery that the metal cathode (or negative pole) disintegrated when the vacuum was of the order of one tenth of a millimeter of mercury; or, say, one ten-thousandth of an atmosphere pressure, and that the finely divided particles, repulsed in all directions from the cathode, would firmly adhere to glass placed near it. Not only silver but other metals could be deposited on glass in this manner to form reflecting surfaces. At first the process was used in a small way in physical laboratories to make non-tarnishable mirrors of platinum-on-glass, but as the result of much experiment the Sputtering process, as it is called, may now be considered a commercial one. The development of high vacuum technique, and the consequent large scale production of pumps capable of quickly producing a vacuum of from one thousandth to one hundred millionth of a millimeter of mercury (ten billionth of an atmosphere), thanks to the electric lamp and wireless valve industries, are mainly responsible.

The apparatus used is shown in Fig. 1. Through a metal stopper in the bell jar B passes a lead from the negative high tension, supporting a cathode K of the metal to be sputtered, in highly purified form. A glass disc D above it and a glass tube T round the lead shields the top of the bell jar from the action. The metal base plate on which the bell jar rests, on a rubber gasket to secure an air tight joint, is the anode, to which the positive high tension lead (1,000 to 10,000 volts) is attached. The current passed through the vessel when evacuated to a pressure of about one ten thousandth of an atmosphere is from 20-50 milliamperes. The glass plate G to be coated is supported at a distance equal to about its own diameter from the cathode and beneath it. A heating coil C is also shown beneath the glass plate. It is essential that the glass plate be thoroughly cleaned, as in chemical silvering, before placing in the bell jar; the cathode is cleaned by sand blasting. A Gaede oil pump is used to exhaust the bell jar, the degree of vacuum being gauged either by a MacLeod gauge or by noticing when the dark space surrounding the cathode (Crookes' dark space) extends to the glass plate. An opaque coating will be deposited in a few minutes. Heavy metals, gold, platinum, silver etc., sputter most readily; 10-15 minutes suffice. Copper, iron and nickel take twice as long; tungsten somewhat longer still; while light metals, aluminium, magnesium, chromium and silicon sputter very slowly. It is advisable, with heavy currents (50 milliamperes), to cool the bell jar by means of a fan, and the cathode by means of a water tank, or even by circulating water through it. The rate of deposition is found to be fairly constant, a layer about one millionth to one hundred thousandth of a millimeter per minute. An opaque coating is about one ten thousandth of a millimeter thick. It is well known that glass adsorbs gas at its surface, and the effect of the bombardment and high vacuum is to release this adsorbed gas, which bursts through the surface of the metal film, tearing holes in it. To avoid this the glass is heated preliminarily by

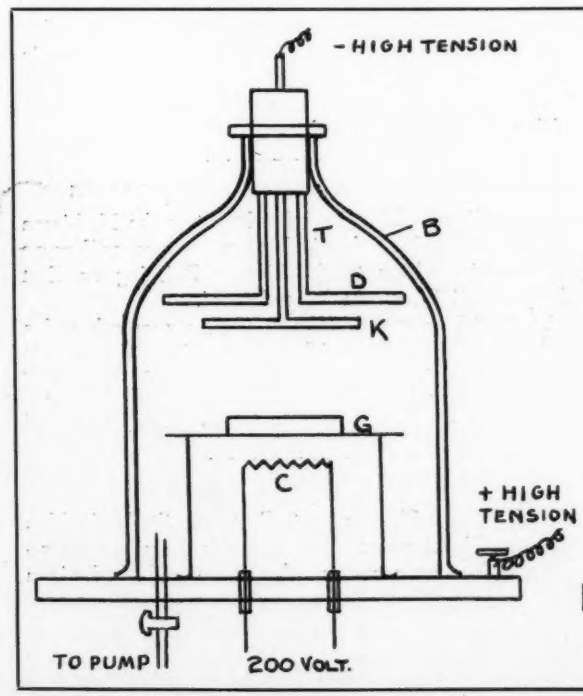

Fig. 1.—Cathodic sputtering by Lee.

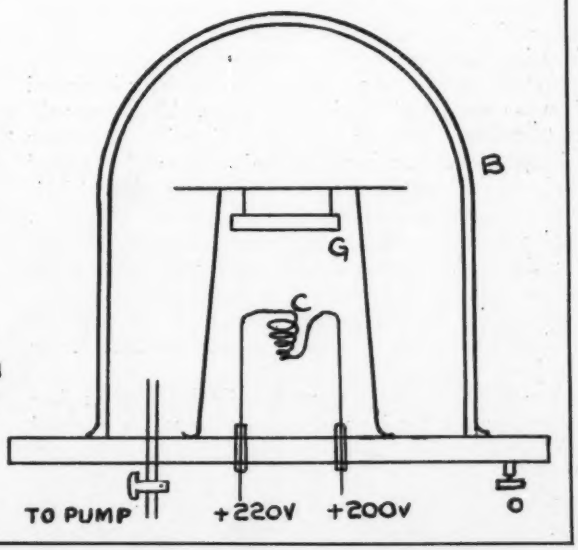

Fig. 2.—Evaporation of metals in vacuo.

means of the coil C, raised to incandescence, which drives off the occluded gas.

There is no object in carrying the process beyond the stage at which the coating is opaque, in fact further sputtering lessens the adherence of the film. The process can be stopped before the film is opaque and a transparent coating is obtained which is often required for optical instruments. Owing to the linear uniform rate of deposition the thickness and opacity of the film after a given time can readily be calculated. When the coating is required to reflect only half the light incident on it, the preliminary heating is not necessary. By the use of templates suspended above and near the glass plate the deposit can be made of any shape, as the template casts a well defined "shadow".

Sputtered silver films are found to be more tenacious than chemically deposited ones, possibly due to the driving off of occluded gases and the thorough drying the surface receives. At present the process is not so cheap as "silvering" in large work but it has many advantages for producing silvered and semi-silvered mirrors for scientific purposes and optical instruments and for making mirrors of other metals which, although not having the reflecting power of silver, are immune from atmospheric corrosion, such as gold and platinum. Other useful metals, aluminum, chromium and silicon are not easily sputtered but can be deposited on glass by another vacuum method discovered by Ritschl in 1931; that is, by evaporation, and it so happens that the metals which are sputtered with difficulty are those which are more easily evaporated.

The general method of depositing metals on glass by evaporation is shown in the diagram Fig. 2, which shows a suitable apparatus for small work. Under the bell jar B the glass to be coated Fig. 2 G, is supported above a coil C of tungsten wire one fifth of a millimeter thick in the form of a helix. This is made into a crucible by coating it with alundum and baking in vacuo; into this the metal to be evaporated is placed. (For metals having a high melting point the alundum must be omitted, the metal being placed in a boat of tungsten filament). It is best to place over the filament a shield which can be raised by an external magnet after the metal has begun to evaporate. This prevents any impurities reaching the glass. The heating coil is raised to a potential of 200 volts above the metal base plate; or a cathode may be passed into the bell jar above the glass plate. This causes the metal vapor to become luminous and assists the process of deposition. In a few minutes the glass will be coated with a strongly adhering coat of the metal, which is robust enough to allow of cleaning with soap and water.

For large mirrors it is necessary to use several coils. Dr. Strong has coated the 36" mirror of the Crossley reflector of the Lick Observatory with aluminum, using twelve coils; the bell jar was made of ¼ inch steel. A uniform coating one thousandth of a millimeter thick was obtained in three minutes.

The metals which can be most easily deposited on glass by evaporation are fortunately those for which extended use can be found. Although silver has the highest reflecting power of any metal in the visible region (92 per cent), this falls off rapidly in the ultra-violet. Chromium has an almost uniform reflecting power of 60-66 per cent throughout; while aluminum has a reflecting power almost equal to that of silver in the visible spectrum, which falls gradually to 80 per cent in the extreme ultra-violet transmitted by the atmosphere. In that region its reflecting power is 5 to 10 times as great as that of silver. Now photography, and especially astronomical photography, is mostly concerned with ultra-violet rays, so that an aluminum-coated mirror is actually 5 to 10 times as efficient as a silver coated one, in addition to its advantage as being non-tarnishable. Process workers at present use silvered glass right angled prisms to produce lateral inversion of the image. These prisms, especially if of large size with faces 4 to 6 inches square, are difficult to produce entirely free from strain. They have three surfaces to be optically worked, while reflection at the entrance and exit faces, and absorption within the prism, reduce transmission by 12 per cent. The aluminum surfaced mirror has only one optical flat surface; there is no glass absorption; the thin slab of glass can easily be produced free from strain, and the aluminum is unaffected by the atmosphere of the process worker's studio establishment.

In the infra-red region of the spectrum chromium has greater reflecting power and greater stability than silver; in fact, its adherence to glass is so great that it is difficult to remove. It has greater reflecting power than silver for infra-red rays and so is useful for investigating that part of the spectrum. For the extreme ultra-violet, wave lengths 1,800 A or less, silicon has high reflecting power and is easily deposited by evaporation. Alloys also can be deposited on glass by this method. The German firm of Carl Zeiss have for some time made mirrors of a magnesium-aluminum alloy, which has high reflecting power which does not sensibly diminish in the ultra-violet region. These mirrors are difficult to produce in optical quality. Recently H. W. Edwards has made mirrors by depositing a magnesium-aluminum alloy (which he has named "pancro"), on glass by evaporation. There are thus limitless possibilities about this new method. Metal films produced by evaporation in vacuo adhere more tenaciously to glass than those deposited chemically, and will stand a reasonable amount of handling, and in fact cleaning with soap and water.

MATHIESON N. Y. OFFICE TO MOVE

In expanding its New York headquarters the Mathieson Alkali Works, Inc., chemical manufacturers, will move its executive offices to the Lincoln Building on East Forty-second Street, on December 15.

They will occupy the forty-sixth, forty-seventh and a major part of the forty-eighth floors. This change will bring to New York the vice president and director of operations and his staff now located at Saltville, Va., where one of the company's plants is located.

TIME FOR FURNACE REPAIRS

Laclede-Christy Clay Products Company, St. Louis, Mo., suggests this as an excellent time for glass furnace repairs. They are carrying a large stock of blocks in a wide variety of sizes for immediate shipment. Shapes from special refractory mix No. 89 can be made to order in five weeks time.

Laclede blocks are trued to exact size which means a minimum of rubbing or cutting to fit on the job.

GLASS PROBLEMS DISCUSSED AT URBANA

PROGRAM OF THE CONFERENCE ON GLASS PROBLEMS

Friday, November 2—1:30 p.m. (at University of Illinois)

1. "Welcome," by Dean M. L. Enger, College of Engineering.
2. "Some Problems and Perplexities in the Glass Industry," by Wm. M. Clark, General Electric Co.
3. "Heat Balance of a Glass Tank," by A. E. Badger, University of Illinois.
4. "The Relation of Natural Gas to the Glass Industry," by C. F. Henness, Pub. Service Co. of Northern Ill.
5. "Combustion of Natural Gas in the Glass Furnace," by James E. McBurney, Owens-Illinois Glass Co.
6. "Fuel Oil versus Producer Gas in Glass Melting," by John Klumpp, Jr., Macbeth-Evans Glass Co.

Friday Evening—8 p.m.

"Applications of X-ray Research in the Glass Industry," by Dr. G. L. Clark, University of Illinois.

Saturday, November 3—9:30 a.m.

7. "Practical Tank Operations," by James Arrandale, Thatcher Mfg. Co.
8. "Batch Constituents and Their Effect on the Durability of Glass," by D. D. Burress, Ball Brothers Co.

THE Second Conference on Glass Problems, held at the University of Illinois, Nov. 2 and 3, under the auspices of the Department of Ceramic Engineering and the Chicago Section of the American Ceramic Society, had an auspicious start with 85 first-day registrants. Late comers, however, swelled the attendance to over 90 at the Saturday session. The registrants came from 12 states with Illinois, Ohio and Indiana leading in the number registered.

Professor C. W. Parmelee, head of the Department of Ceramic Engineering, and chairman of the first day's meeting, in an opening address expressed his appreciation to those who had contributed largely to the success of the Conference. Dean M. L. Enger, of the College of Engineering, was then introduced and welcomed the group on behalf of the University authorities.

In his talk Dean Enger explained the functions of the Engineering Experiment Station in carrying on research activities. He stated that the Station was the oldest of such organizations, having completed slightly more than 30 years of scientific service. His hopes for a successful meeting were fully realized by all present.

A number of interesting papers on the different technical phases of the glass industry were presented at the various sessions of the Conference. Abstracts of these papers follow:

Some Problems and Perplexities in the Glass Industry:

By Wm. M. Clark, General Electric Co.

The U. S. Bureau of the Census shows that the value of glass products manufactured in 1933 was $192,000,000. This is a decrease from the preceding two years. The number of glass plants also showed a decrease. The output of the stone, clay and glass products industry ranked eighth in amount.

The arrangement of a glass plant may be a result of natural growth or planning. While many successful glass plants are of the first kind, the planned layout is more satisfactory. In locating a glass plant, there are many factors which must be considered. The novice, in searching for technical information on glass, is practically forced to read in the German language.

The age and tradition of the glass industry may tend to make the practically-trained man skeptical of the advice of the technical worker. Both should understand the possibilities of mutual help.

Many glass factories have failed because of production of inferior ware. A demand for ware at profitable prices provides a legitimate business excuse.

The location and plant layout may sometimes be profitably entructed to an expert consulting engineer.

Absolute uniformity in the glass manufacturing process is conducive to the sustained production of good quality ware. There are many points in the process at which non-uniformity can enter. The weighing equipment should be suitable and accurate.

While glass technology is far from an exact science, numerous applications may be carried over from other related fields. The glass laboratory can be a valuable agent in perfecting control methods as well as smoothing out difficulties which arise in the manufacturing processes.

The cost of glass making machinery has risen many fold since the introduction of the first machine. The resulting revolutionary change in manufacturing methods has brought about a need for readjustment of deserving labor.

The public should be cultivated to appreciate good, artistic work in glass and artisans should be encouraged.

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Heat Balance of a Glass Tank:

By A. E. Badger, Dept. of Ceramic Eng. Univ. of Illinois

Fuel cost is the source of one of the large expenses in glass manufacturing. The purpose of a heat balance is to show how the heat derived from fuel is used. This is a summary of a test made in cooperation with Mr. H. I. Vormelker of the General Electric Company and the Technical Staff of the Pitney Glass Works.

The test described was made on a continuous tank furnace for melting glass for the Corning ribbon bulb machine. The batch of sand, soda ash, nitre, feldspar lime and cullet is fed automatically into a 20 x 50 ft.

melting chamber. The daily capacity is about 100 tons. The tank holds 300 tons of glass.

At the time of the test, the tank was ten months old. Natural gas was burned from seven ports on each side of the tank. Cast fused mullite blocks were used for the side walls, and clay flux blocks for the bottom of the tank.

The total heat entering the furnace in 24 hours was found from the volume of gas used, times its calorific value, plus the sensible heat introduced in the entering air.

From thermochemical data it was computed that 16.5 per cent of the total heat input was used in the glass making process. About an equal amount of the heat input was lost up the stack.

The data used were, areas obtained from blueprints of the tank, the temperature of the tank structure surface as shown by copper-constantan thermocouples, and the temperature of the air surrounding the tank. The losses were computed as about 40 per cent of the heat input.

It was found that the regenerators absorbed 53 per cent of the total heat input and returned about four-fifths of this amount to preheat the combustion air.

Other small losses occurred in use of cooling air and cooling water.

Unaccounted for losses amounted to about 1/6 of the total heat input. These unaccounted losses may be due to radiation from openings, loss to ground and errors in convection formulas.

In the discussion, it was suggested that leakage of air into the flues may give false values in the calculation of excess air of combustion. It was brought out that there may be appreciable leakage of heat through cracks in the crown. The tendency for flue gases to stratify makes accurate sampling for flue gas analyses difficult.

The discussion also touched upon the possibility of glass tank insulation. Regenerators and necks of ports may be insulated. Tank blocks may be insulated if seams between them are left uncovered.

It may be possible to use sillimanite blocks in tank crowns to permit tight joints.

This paper will be published in full in the January issue.

●

The Relation of Natural Gas to the Glass Industry:

By C. F. Henness, Pub. Service Co. of Northern Ill.

In introducing his subject, Mr. Henness presented a short motion picture which showed steps in the building of the pipe line to carry natural gas from the Texas fields to the Chicago area.

The centers of large-scale glass manufacturing in Ohio, West Virginia and Pennsylvania developed near natural gas supply sources. The availability of this gas at other points resulted in the location of glass plants nearby, if conditions warranted it.

To make good glass is the primary object of manufacturers. Fuel is an important item in manufacturing costs. The flexibility and controllability of gas make its use popular where heat is needed in glass making processes.

In the Chicago area, natural gas, in open-fired burners, has been used to improve lehr operation where the alteration of the original oil-fired equipment to produce the desired results would have proved too expensive. The quality and uniformity of ware coming from a decorating lehr has been improved by the use of a multi-burner gas installation in the equipment. Other successful applications of natural gas are for fire polishing and in the glory hole.

Natural gas is well fitted as a tank fuel for use with the high speed melting that is necessary for fuel economy. The flexibility lends itself to the careful handling that is required in reducing the melting area from 15 or 20 sq. ft. per ton of glass per day to as low as 6 sq. ft.

By the proper technique, it is possible to get the luminous flame which aids the elimination of hot spots in the tank.

●

Combustion of Natural Gas in the Glass Furnace:

By James E. McBurney, Owens-Illinois Glass Co.

Of glass furnaces in operation, about 85 per cent are large tanks of 50 to 150 tons daily capacity. The most of these are recuperative. While smaller tanks and furnaces are important, the operation of the large ones is considered here.

The construction and principle of the glass tank furnace are similar to the open-hearth metal melting furnace. Both use cross-fire, which periodically originates from opposite sides of the furnace chamber. The glass tank is continuous in operation, while the metal furnace operates periodically. In spite of this, the results obtained in the operation of one have application in the conduct of the other. A highly luminous flame hugging the melt surface is best practice. The step off from the port opening to the glass surface prevents a closely sweeping flame in the glass furnace.

Producer gas has ideal properties for combustion in the glass furnace but the making and close control are difficulties in its use. Natural gas has a gross heat content of 950 to 1250 b.t.u. per cu. ft. and a net content of about 10 per cent less. Net values should be used in comparing gas qualities. The higher the hydrogen content, the greater will be the diffference between gross and net heating values. The hydrogen is contained in the composition of the various gases present in natural gas (methane, ethane, etc.).

Of the gases composing natural gas, methane is the most difficult to break down. The higher the methane content, the slower is the flame speed. Luminosity in the flame results from the cracking of the gases and the release of carbon particles. The particles are heated to incandescence and a visible flame results.

In general, we may summarize three methods for getting heat from the hot gases to the glass: radiation from luminous and non-luminous gases, convection and conduction. It is impossible to say what difference there is in radiation from the luminous or non-luminous gases. Some heat is radiated from heated furnace wall, but most of the heat taken up by a wall is conducted outward, not radiated to the interior.

Some of those attending the Second Conference on Glass Problems were (left to right): First row: sitting, McCauley, Vormelker, Peterson, Purdy, (Mrs. Purdy) Carpenter, Kaeppel, Curts, Parmalee, Walters. Second row: Love, Duval, Hursh, Burress, Durr, Wales, Durhalt, (Andrews) Linder, Black, Schneider, Lanzinger, Blain. Third row: Grubel, Weil, Middleton, Lyon, Crawford, Reese, Campbell, Raffensperger, Ellis. Fourth row: Hewitt, Bradley, Mundy, Arrandale, James Arrandale, Spengler, Klumpp, Jr., Barton, McComas, Plankenhorn, Swearengen, Flint. Fifth row: Steinhoff, Board, Motsch, Shute, Pittman, Tooley, Henness, Tindall, Conover, McCormick, Hanson. Sixth row: Schaefer, Serviss, Babcock, Kraner, Oakley, Fryling, Badger, Clark. Seventh row: Schreiner, Owen, Hopkins, Burch, Waleworth, Ryan, Mulholland, Bowes, Pruden, Koupal, Taylor.

It is possible to get satisfactory melting with non-luminous flames but higher flame temperatures are required when this procedure is followed.

To produce luminous flame, natural gas is fed from ports to meet the air in the furnace. The gas is usually under 10 oz. of pressure. The velocity of the gas passing across the furnace is highly important. A less luminous flame results from improper velocity. The correct velocity varies with the particular natural gas being burned. The "cut and try" method shows the best velocity to use to get a flame of maximum luminosity as shown by visual inspection. To get full luminosity the gas and air should enter the furnace at the same speed and should mix without turbulence. About 20 per cent of change in velocity is considered permissible without marked debasement of operating condition.

Luminosity tends to eliminate hot spots and it saves fuel. The use of heated air is also a fuel saver.

In the discussion it was brought out that colors causing maximum luminosity are beyond the range of human vision, but that the visible luminous carbon particles may serve as a guide toward maximum radiation conditions.

The question was raised concerning possible injurious effects of radiation from fully luminous flame upon the ports. Mr. McBurney replied that he had no experience which would point toward increased port deterioration.

●

Fuel Oil Versus Producer Gas in Glass Melting:
By John Klumpp, Jr., Macbeth-Evans Glass Co.

In choosing between two fuels, there are other factors to consider beside the original price. Some of these factors are:

1. Capital charge on equipment necessary.
2. Maintenance of furnace equipment.
3. Quality of glass produced.
4. General plant cleanliness.
5. Labor requirements.
6. Reliability or continuity of service.
7. Cost of fuel delivered at ports or burners.

Because of simplification of equipment, furnace costs show about 20 per cent difference in favor of oil burning over producer gas. The difference in furnace maintenance is negligible. Good quality glass may be made with either fuel, the choice here depends on uniformity of conditions. Change in coal brings a change in producer gas; oil, too, may vary. Fuel oil has an advantage in respect to plant cleanliness. Either may be made reliable in operation by duplication of units.

The cost of fuel delivered to the port or burner is a factor of major importance. Mr. Klumpp gave some figures based on requirements for two tanks of 780 and 600 sq. ft., respectively. With the necessary equipment and labor, using one-half ton of coal per ton of glass produced, the coal having a calorific value of 13,700 b.t.u. per pound, the cost of supplying gas to melt one ton of glass with producer gas was found to be $3.18. This was estimating coal at $4.50 per ton. If 64 gallons of fuel oil of 147,000 b.t.u. per gallon at $.043 per gallon are required to melt a ton of glass, then the cost of supplying fuel for melting one ton of glass in the two

tanks becomes $3.00. In this first case, it is quite possible that slight changes from the conditions assumed would bring the cost of delivered fuel to the same level.

In a smaller plant which might be melting 60 tons of glass per day in five twelve-ton tanks, the coal consumption is given as 2/3 ton per ton of glass produced. The oil consumption is correspondingly increased from the above case. In this smaller installation the calculation of the cost of fuel delivered to the tank per ton of glass made is $4.52 for coal and $4.16 for fuel oil.

These estimates are based on average practice. Some plants may show better economy in operation.

Properties to be considered in selection of fuel oil are viscosity, flash, B. S. & W., cold test and b.t.u., also the content of sulphur, carbon residue, ash and iron. Some oils do not give sufficiently clean combustion for use in glass melting. A complete study of the heating values of fuels for glass furnaces has been published in The GLASS INDUSTRY.

When using oil equipment, the oil should be screened at several points; if the oil is heated, the conveying pipes should be insulated and the heater thermostatically controlled; thermometers should be placed in the oil line near the burner; pressure regulators should be used; and provision should be made for drainage of water from the oil storage tank.

●

Applications of X-ray Research in the Glass Industry:

By Dr. G. L. Clark, Department of Chemistry University of Illinois

The use of the X-ray as a research tool was explained by Professor Clark at the evening meeting of the Glass Conference. The lecture was well illustrated by use of numerous slides.

The speaker described the various uses of X-rays in medical and industrial radiography, and in studying materials by their diffraction properties. The development of the latter subject occupied the most of the lecture. In this connection, it was pointed out that X-rays, with wave length of about one hundred millionth of a centimeter, are of the same order of magnitude as planes determined by atoms in crystals. These planes serve to diffract the X-ray beam passing through the crystal to give a characteristic pattern which may be registered on a photographic film.

Illustrations of various types of X-ray diffraction patterns were given. Among these were several given by substances generally considered amorphous. It was shown that patterns given by glasses could be matched with crystalline patterns by suitable statistical treatment.

Professor Clark explained the Warren theory of structure of glass. This theory is borne out by X-ray observations and explains glass formation by substances whose crystals are composed of closely knit units which are held together more loosely. Silica is of this type.

In concluding his lecture, Professor Clark showed diffraction patterns from metals in various states of strain and crystal orientation from working. Because of the diffuse diffraction patterns given by glasses, the X-ray technique, in its present state of development, cannot be used for strain studies.

Practical Tank Operations:

By James Arrandale, Thatcher Mfg. Company

The trade demand for durability has led to consideration of tank operation as many defects, too numerous to classify, have their origin in the tank.

For successful tank operation, the batch should be properly mixed, the fuel should be uniform and of the same quality and the furnace man should be informed of changes in the batch. Producer gas must be watched closely, and oil deserves even more attention as to quality than natural gas. The tank operator should understand the gas producer as well as the effect of combustion conditions upon the glass.

The quick melting of glass is the best practice. Improved quality of ware results from uniformity of operating conditions.

This paper will be found printed in full elsewhere in this issue.

●

Batch Constituents and Their Effect on the Durability of Glass:

By D. D. Burress, Ball Bros. Co.

One of the great problems confronting the glass industry today is that of durability. A large amount of work has been done on this subject at various centers, particularly by Dr. Turner and his co-workers at Sheffield.

Most glasses of commercial importance are soda, lime and silica with possible additions of other oxides. Of these, alumina has been the subject of many papers, few of which deal with durability.

Hodkin and Cousen present the theory of effect of moisture on glass surfaces, outlining the accompanying chemical reactions. Any glass making agent which contributes to resistance to action of water may be classed as a stabilizing agent. Auerbach has shown the strong effect of alumina in increasing surface hardness of glass and undoubtedly this carries over to chemical durability. Dimbleby and Turner have shown that alumina is very effective in increasing durability.

Boric oxide has been shown to be an effective stabilizing agent in glass. It is important in its fluxing action to permit the use of larger percentages of alumina at lower melting temperatures, simultaneously improving other qualities.

Magnesium oxide has some use as a stabilizing agent. Barium compounds are valuable batch constituents because of their active fluxing ability, particularly in glasses where alumina is a constituent.

In the discussion of Dr. Burress' paper, the comparative stabilizing abilities of different oxides were brought out.

Dr. Bowes gave a short summary of the discussion of the subject of durability as presented at the Summer Meeting of the Glass Division of the American Ceramic Society and of the plan to carry out durability studies on standard glass samples in a number of different laboratories throughout the country. This work, under the auspices of the Bureau of Standards, is directed toward a standardized test or tests for chemical durability.

Further brief discussion of the subject of the paper led to the mention of the effect of surface condition upon durability.

THE MECHANICAL STRENGTH OF GLASS*

Editor's Note.—This work originally appeared in French in the Bulletin de la Société d'Encouragement pour l'Industrie Nationale, Ser. 5, Vol. 4, p. 838 et seqq, 1899; that is to say, 35 years ago, before Glass Technology undertook to become a science in its own right. We do not know a great deal more about the mechanical properties of glass now than we knew then, and M. Grenet's work is by no means out of date.

The later part of this article in particular is of great importance. Since various individuals, companies, and committees are studying this problem, it may be useful to have an English version of M. Grenet's work, which might just as well have been written in 1934 as in 1899.

THE mechanical strength of glass is of interest in view of its practical importance, but its resistance to compression is almost always more than ample (around 60 kilograms per square millimeter—85,000 lb./sq. in.),[1] and it is generally[2] the inadequacy of its resistance to tension which leads to its breaking.

We have carried out some tests bearing solely on the resistance to tension of a given glass (St. Gobain's). The object was more particularly to determine the influence of various experimental conditions. We give below the chemical composition of the St. Gobain glass.

St. Gobain's No. 4 Glass		*St. Gobain's "Cathedral" Glass*	
SiO_2	71.75%	SiO_2	70.98%
$Al_2O_3+Fe_2O_3$	1.50	$Al_2O_3+Fe_2O_3$	1.56
CaO	14	CaO	14.94
Alkali & SO_3	12.75	Alkali & SO_3	12.52

Cross-Bending Tests

We worked with glass annealed in ovens; first, on plates of number 4 glass with polished faces; secondly, on plates of cathedral glass whose faces were "rough-rolled" (cast); thirdly, on rods of number 4 glass.

The glass plate rested freely on two iron knife-edges, 10 cm. apart (about 4"). The load was applied in the middle of the specimen by a little iron prism, 3mm. on a side, whose edges were parallel to the knife-edge and supports. To assure an even contact, a strip of rubber was glued on the face of the prism in contact with the glass. The weight used for producing rupture was applied at the middle of the iron prism through an intervening knife-edge; in this way the load was spread uniformly and there was no reason to fear that one side might be more heavily loaded than the other. The load was formed of a bucket into which water could fall in a steady and uniform stream.

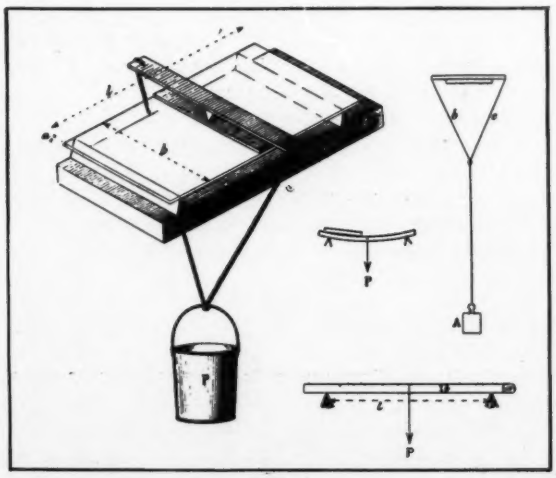

FIG. 1

Results of Tests: In our cross bending tests on plates, the initial load (the weight of the bucket and accessories) was 2.35 kilograms (around 4½ lb).

$$\text{Formula used: } R=\frac{3}{2}\cdot\frac{Pl}{ba^2}$$

Rate of loading: 1 kilogram in 4 minutes.

Plates of number 4 glass. Edges polished.

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
3.0 x 25.0	8.25	5.50	7830
2.64 x 23.5	4.95	4.62	6580
2.77 x 25.0	6.35	4.96	7100
2.695x 25.2	5.90	4.83	6860
2.28 x 25.5	4.10	4.68	6680
2.21 x 25.5	3.85	4.63	6600
3.0 x 25.0	8.25	5.50	7830
2.70 x 25.0	4.95	4.07	5800
2.71 x 23.8	6.35	5.44	7750
2.78 x 25.0	5.45	4.23	6020
2.74 x 25.0	5.74	4.57	6510

Number of Tests 11

Mean value of Modulus of Rupture, 4.82 kg/mm² (6870 lb./sq. in.).

Maximum Strength observed, 5.50 kg/mm² (7830 lb./sq. in.), 14% above average.

Minimum Strength observed, 4.07 kg/mm² (5800 lb./sq. in.), 16% below average.

Plates of Number 4 glass. Edges smoothed but not polished.

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
2.59 x 23.5	5.05	4.91	7000
2.61 x 24.5	4.85	4.35	6200
2.11 x 24.5	3.70	5.1	7260
2.15 x 25.0	4.50	5.85	8330
2.36 x 26.0	4.60	5.85	8330
3.02 x 25.2	6.65	4.35	6190

Number of Tests, 6.

Mean value of Modulus of Rupture, 4.90 kg/mm² (6990 lb/sq. in.)

Maximum Strength observed, 5.85 kg/mm² (8330 lb/sq. in.), 19% above average.

Minimum Strength observed, 4.35 kg/mm² (6190 lb/sq. in.), 11% below average.

We see that the results do not differ appreciably as a result of changing the "finish" on the edges from "polish" to "smooth".[3]

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*A Report of Investigations carried out by M. Grenet, Mining Engineer, under the auspices of the Society for Encouraging French Industries.

[1] *Translator's note.* There is no known limit to the compressive strength of glass: the figures quoted above are a property of the testing machine, not of the glass itself.

[2] *Translator's note.* The word "generally" could be replaced by "invariably" with advantage.

Ignoring then the state of the edges and lumping the whole 17 experiments together, the average tensile strength is 4.84 kg/mm² (6880 lb/sq. in.).

Cathedral Glass, with Polished Edges.

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
4.4 x 23.0	9.95	3.58	5100
4.21 x 21.5	11.65	4.62	6580

Number of Tests 2

Average Modulus of Rupture, 4.10 kg/mm² (5830 lb./sq. in.).

Cathedral Glass, with Smoothed Edges

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
4.24 x 24.5	15.45	5.26	7500
4.44 x 22.0	12.45	4.30	6120
4.10 x 25.0	11.48	4.10	5820

Number of Tests, 3.

Average Modulus of Rupture, 4.55 kg/mm² (6480 lb./sq. in.).

In the tests below we failed to take notice whether the side with the diamond cut on it was in compression or tension.

Cathedral Glass Cut with Diamond

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
4.19 x 26.0	16.25	5.37	7630
4.35 x 25.5	14.45	4.52	6430
3.72 x 25.0	10.75	4.67	6620
3.50 x 26.5	11.35	4.75	6760

Number of Tests, 4.

Average Modulus of Rupture, 4.82 kg/mm² (6850 lb/sq. in.).

The effect of variations in the condition of the edges seems to be a little more pronounced in cathedral glass than in number 4 glass, but this may be a result of the small number of specimens tested.

Total number of tests on cathedral glass, 9.

Average Modulus of Rupture, 4.57 kg/mm².

Maximum Strength observed, 5.37 kg/mm², or 18% above average.

Minimum Strength observed, 3.58 kg/mm², or 22% below average.

We see that in these tests, with rates of loading similar in all cases, the strength does not vary in any clear cut fashion with the state of the surfaces or of the edges.

The strength of number 4 glass is a little higher than found for cathedral glass, but the difference is slight and may be attributed to its greater thickness, which causes the rate of loading per unit of area to be less.

Rate of loading: 1 kilogram in 13 minutes.

Glass number 4. Polished edges.

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
3.0 x 25.5	4.70	4.54	6450
2.66 x 23.7	4.70	4.21	6000
2.91 x 25.0	4.35	3.10	4420
2.85 x 25.0	4.35[4]	...	....

[3] *Translator's Note.* The term "douci" (literally softened, smoothed, or mellowed) is incorrectly rendered in some dictionaries as "polished". It really means, "finely ground," the stage ahead of polishing. The technical English expression is "smoothed". The glass normally passes through a "roughing" stage (rough grinding with sand), "smoothing" (usually with emery), and "polishing" (with rouge).

The last specimen broke at a point 15 mm. from the center of the span. The strength at the center was therefore greater than 5.40 kg, and the strength at the point of rupture was 3.80 kg.[5]

The departure of the resistance or strength (from its proper or maximum value in the same plate) at 15 mm. distance, is in this case 35 per cent.

Number of Tests, 4.

Mean value, 4.21 kg/mm².

Maximum Strength observed, 5.70 kg/mm², or 28% above average.

Minimum Strength observed, 3.10 kg/mm², or 26% below average.

Glass Number 4. Smoothed edges

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
24.5 x 2.84	4.70	3.56	5050
24.5 x 1.95	5.20	...	....

The last plate broke at a point 10 mm. from the center: it follows that at the center the strength exceeded 4.21 kg/mm², and at the point of rupture, the strength was 3.37 kg/mm².

Average of 8 tests, ignoring differences in state of edges—4.02 kg/mm². [6]

We see that when the rate of loading is 1 kg. in 12 minutes, the average strength is a little lower than when the rate of loading is 1 kg. in 4 minutes. The difference becomes clearer with an extremely slow rate of loading.

Rate of loading: I kg. in 4 hours

Glass Number 4. Smoothed edges

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
2.55 x 24.2	3.75	Broke 15 mm. from center. R>3.6 at center R=2.51 at point of fracture.	
3.00 x 24.5	4.35	2.95	4200
2.55 x 24.5	3.15	2.97	4220
2.74 x 23.2	4.10	Broke 9 mm. from center. R>3.39 at center R=2.78 at point of fracture.	

Number of tests, 4.

Average Modulus of Rupture, 3.03 kg/mm²

(Translator's Note. We condense the next page of the French version, by saying that tests made with diamond cut edges gave substantially the same modulus of rupture as those with smooth edges, and further that taking the polish off the lower face of the glass by cross-grinding it did not reduce the strength. The edges also were "depolished". M. Grenet concludes that the state of the surface, and of the edges, is unimportant, at least with slow rates of loading. This conclusion seems very extraordinary, and cannot always be true; but the translator, in his own experiments has *sometimes* found the same surprising result.

M. Grenet, averaging all his tests of slow loading (1 kg. in 4 hours) finds a mean value of the Modulus of

[4] *Translator's note.* There is apparently a misprint here in the original French, where the value is given as 7.35 kg/mm². We have done the best we can about it.

[5] *Translator's note.* This habit of glass laths of breaking at a point where the stress is much less than the maximum, naturally results in some perplexity as to how results should be expressed. The translator's staff is engaged at present in trying to devise means of minimizing this trouble.

[6] M. Grenet gives various other statistics which we have omitted as unimportant.

Rupture of 3.12 kg/mm² (4430 lb/sq. in.), and concludes that the strength under slow loading, that is, under prolonged stressing, is appreciably less than under normal experimental rates of loading.)

Effect of Very Rapid Rates of Loading

We have made a few tests of very rapid loading, in order to see what influence it might have on the strength. For this purpose we applied the breaking load through the intermediary of a steel-yard lever, whereon was suspended a 15 kg. weight, considerably more than was necessary to produce fracture.

As the weight descended until the glass broke, a little pointer indicated the maximum effort exerted by the steel yard; this was the breaking load.

Loading up to the point of rupture was thus effected in a space of time varying from 5 to 10 seconds.

Section of plate in mm. a x b	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
2.60 x 25.0	9	7.99	11350
2.85 x 26.0	8	5.68	8100
2.85 x 25.0	10	7.39	10500

Average Modulus of Rupture ..... 7.02 kg/mm² (10,000 lb./sq. in.)

We see that this very rapid loading gives a notable increase in strength.

We have made another test by measuring the work needed to produce rupture in one of our glass plates; for this purpose we allowed a weight "A" of 100 grams to fall from increasing heights until the glass broke.

The iron prism pressing on the glass was connected directly to the weight "A" by two equal strands of twine, b and c, so that the pressure was distributed substantially evenly over the whole surface of contact.

To break the glass it was necessary to allow the 100 gram weight to fall from a height of 800 to 850 millimeters.

(Translator's Note. The author (M. Grenet) here proceeds to deduce the equation which was given again by the translator (F. W. Preston) thirty-two years later as a correction of the Tuckerman formula used by Williams. See J. Amer. Ceram. Soc. Vol. 14 (1931) p. 428 and 432.

The French version is full of misprints, and it is questionable whether we should try to correct them in a translation, but the final result is *right*. It is,

$$\text{Modulus of Rupture } (R) = \sqrt{18\ ET/V}$$

where R is the stress which we call the Modulus of Rupture, E is Young's Modulus of Elasticity, T is the work done in effecting rupture (which is equal to the potential energy lost by the weight in filling), and V is the volume of the glass plate being tested.)

Young's Modulus for Glass, as given in books, is around 7000.[7] This figure agrees with those found by ourselves in several tests.

E=7000 kg/mm².
l=100 mm.
b=24 mm.
a=2.71 mm.
T=0.1 x 850 kilogram-millimeters of work

} whence R=25.5 kg/mm² R=36,200 lb./sq. in.[8]

In this experiment, the increase of strength cannot be ascribed to inertia, which would diminish the volume of glass available for absorbing the energy, and so the calculated value of "R" could only be too *low* on this account.

But maybe there is a good deal of energy lost by reason of the stretch in the strands of string which connect the weight to the loading-prism, and the stress in the glass would thus have a lower value than calculated above.[9]

Cross Bending Tests of Rods of Number 4 Glass

The cross section of these rods was substantially circular. Rods which were not perfectly round, and for which we have indicated two diameters, the maximum and minimum, have been treated as elliptical for purposes of calculation.

The glass rod rested freely on two knife edges 10 cm. apart, and the load was applied centrally.

When the rod was not circular in section, the largest diameter was always placed horizontally.

Formula used

$$R = \frac{8\,Pl}{\pi\,ab^2}$$ [10]

Experimental Results

The initial load on the rod tests was 0.430 kg.

Rate of loading; 1 kg. in 4 minutes

Diameter in mm.	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
5.80	5.512	7.20	10230
4.69	2.912	7.35	10500
4.74	2.66	6.61	9400
5.24	3.96	7.05	10100
2.51	0.53	8.50	12100
4.02-4.45	1.83	6.48	9200
3.65-3.80	1.53	7.70	10950
4.86	3.33	8.15	11600
5.63	4.48	8.30	11800

Mean value of Modulus of Rupture ..... 7.54 kg/mm² (10,700 lb./sq. in.)[11]

Rate of loading: 1 kg. in 12 minutes

Diameter in mm.	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
3.45-4.24	1.43	7.22	10300
3.46-4.26	1.53	7.74	11000
4.73-5.15	2.48	5.48	7800
4.44-4.35	1.83	5.55	7900

Average of 4 tests, 6.47 kg/mm.²=9,200 lb./sq. in.

Rate of loading: 1 kg. in 4 hours

Diameter in mm.	*Load in kg. at rupture*	*Modulus of Rupture kg/mm²*	*lb./sq. in.*
6.60-5.09	3.06	4.56	6500
5.30-4.87	1.66	3.36	4800
5.42-4.81	1.84	3.74	5300
5.82-4.93	2.01	3.78	5370
5.08-6.27	2.96	4.66	6650
5.40-6.98	3.06	3.83	5440

Average Modulus of Rupture ..... 3.99 kg/mm² (5670 lb./sq. in.)

We see that the strength as determined from the flexure of rods is notably higher than the values given by the

[7] *Translator's note.* Kilograms per sq. mm. In English units, 10,000,000 lb./sq. in.

[8] *Translator's note.* This figure is not acceptable to the translator as a physical property of the glass, but only as a statement of the results of particular experimental set-ups.

[9] See footnote (8).

[10] *Translator's note.* R—Modulus of Rupture in kg/mm.²; P— load in kg. at rupture; l—span (100 mm); a—larger diameter of rod, b—the less diameter, both in mm.

[11] *Translator's note.* There are nine tests listed above, but the French text then proceeds to state that there were seven. This is presumably another misprint. This and certain other comments are therefore omitted from the translation.

plates. None the less, at the slow rate of loading of 1 kg. in 4 hours, the results become quite comparable.[12]

We have sought to find out what weight would have to be hung on the rods to produce their rupture after a very long time. Below are given the results of several tests:

Diameter in mm.	*Breaking Load-kg*	*Maximum Stress Supported* *kg/mm²*	*lb./sq. in.*	*Comments*
3.76-3.70	0.402	1.99	2830	Not broken at end of 3 mos.
3.76-4.80	0.810	3.40	4820	Broken at end of 5 days.
4.80-5.04	2.	4.38	6200	Broken at end of 4 days.
5.17-4.03	0.830	2.51	3570	Not broken at end of 3 mos.
4.03-4.90	0.380	3.01	4290	Broken at end of 1 day.
3.14-3.20	0.380	3.00	4270	Broken at end of 2 days.
5.90-4.70	1.530	2.99	4250	Not broken at end of 5 days.
5.90-4.70	1.830	3.58	5100	Same rod as last mentioned. broken at end of one day.

We see that for the rods, the breaking load is still around 3 kg/mm².

Tests in Direct Tension

We have made only an insignificant number of tests, and cannot derive any conclusions from them.[13]

Rate of loading: 1 kg. in 4 minutes

Number 4 Gass Annealed

Diameter in mm.	*Breaking Load (kg)*	*Breaking Stress in kg/mm²*	*lb./sq. in.*
1.15	9.42	9.00	12800
0.75	3.89	8.80	12500

Number 4 Glass, not Annealed

Diameter in mm.	*Breaking Load (kg)*	*Breaking Stress in kg/mm²*	*lb./sq. in.*
0.80	6.03	12	17000

Deformation Preceding Rupture[14]

We have tried to determine whether the delay in fracturing in the cross-bending tests was accompanied by a permanent deformation or "set", increasing slowly from the time the load was applied up to the moment of rupture.

For this purpose we took a plate of number 4 glass, 25 x 3 mm. in section (1″ x ⅛″), with smoothed edges and loaded it in the same manner as in the breaking tests, applying the load at a rate of 1 kg. in 2 minutes until a stress of 4 kg/mm² was developed.

A "test-plate" of glass was then placed on the specimen whose strength was under investigation, and the combination was illuminated with the yellow sodium flame.[15]

With the aid of a magnifying glass, one of the interference fringes, thus produced, was watched attentively.

While the specimen was being loaded, the deflection of the glass produced a displacement of the fringes, and as soon as the flow of water into the bucket was stopped and the load became constant, the fringes ceased to move.

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[13] *Translator's note.* A factor that M. Grenet did not take into account is that he used rather larger rods for his slow loading tests, and as pointed out by Griffiths and others, small rods give higher strengths than large ones. Even in the test at 1 kg. in 12 minutes, this effect seems to be showing up.

[12] *Translator's note.* Apart from the different method of testing (direct tension as against flexure), M. Grenet has gone to the use of smaller diameter rods, with a natural increase in apparent strength.

[14] *Translator's note.* These observations appear to me the most valuable part of M. Grenet's tests.

[15] *Translator's note.* This "interference" test is unfamiliar to most glass manufacturers, but is well understood in physical laboratories, and is shop practice in optical-glass working plants.

This large glass mural, engraved, colored and specially illuminated, graced the exhibit of Union Carbide and Carbon Corporation at A Century of Progress. It is 55 feet long, the largest of its kind in the world.

CHECKER BRICK FOR REGENERATORS

AS A HEAT machine the glass tank furnace is known to be remarkably inefficient. Heat balances of various glass furnaces show that only 10 to 20 per cent of the total heat input is actually utilized in the melting process, and that while there is a considerable loss of heat through radiation, the larger percentage of lost heat is carried away by the products of combustion. In order to recover as much of this heat loss as possible, and to insure high flame temperatures, the glass industry has followed in the steps of the steel industry and has to a great extent adopted the Siemens regenerative principle of heat recovery.

As the efficiency of the regenerator system is just as essential to efficient furnace operation as is the use of the proper fuel, correct combustion, etc., it is surprising to find that many glass plants pay little or no attention to the make up of the regenerators. In some cases it is not realized that a checker brick must be something more than a common second-grade fire brick, and that a checker brick to be efficient must possess certain physical properties that are not only desirable but are also extremely essential. In other cases there is a distinct aversion to the use of the newer, specially designed checker brick. This may be due to the lack of a realization that the use of such brick can increase the regenerator efficiency with the result that it is possible to obtain higher flame temperatures, greater heat input into the furnace and, finally, lower production costs.

The action of the regenerator is as follows: the flame-gases and dust are passed out of the furnace through chambers filled with checker brick piled tier on tier in a definite geometrical pattern. By the means of reversing valves the direction of the movement of air is reversed at regular intervals. When the incoming air passes up through the heated checker brick and is preheated, the flame-gases are passing down the opposite regenerator or chamber and losing their heat to the checker brick cooled by the previous incoming air. This brief description of the duties of the checker brick is necessary for a full understanding of its essential physical properties.

Checker brick, especially that variety used for the hottest zones, must have a P.C.E. value sufficiently high for the temperatures encountered, which in ordinary furnace practice vary between 2000° and 2700°F. Brick of low pyrometric cone equivalent, if used in this range of temperature, is apt to deform and clog the checker passages to such an extent that a shut down and repair is necessary. Along with the high P.C.E. value the brick should possess a high mechanical strength and a high resistance to deformation under load at high temperatures. These properties are particularly important when bottom heating is used for the heating up of cold regenerator chambers. Under these conditions the supporting arches and lower tiers of checker brick are subjected to higher temperatures than usual and may collapse if lacking in these properties.

As the flame-gases from the furnace carry with them a large amount of abrasive (sand) and fluxing (alkaline dusts) material at a high velocity, the checker brick must be such that it can resist both the abrasive and fluxing action of these dusts. The increasing use of mechanical batch feeding methods has, however, decreased the importance of these two properties to some extent.

A high resistance to spalling is also extremely important. Fundamentally, the operation of the regenerator system is a continuous cycle of cooling and heating; hence, the regenerator filling will rapidly go to pieces if the brick cannot withstand sudden and frequent changes in temperature.

From a heat recovery standpoint the most important and desirable property of the checker brick is a high thermal conductivity and a high specific heat. High thermal conductivity is necessary in order that the brick may absorb and release heat rapidly; high specific heat (capacity for heat) means that larger quantities of heat may be stored per pound of brick.

Progressive checker brick manufacturers have realized the importance of these physical properties and have spent considerable time and money in in-

TABLE I

Comparative Data for Various Types of Chequer Brick.

No.	Type of Brick. Name.	Shape.	Wall Thickness.	Size of Flue.	Free Area, %.	Wt. in lb. per cu. yd.	Heating Surface per cu. yd.
1	4" hexagon		solid	2" 4" hexagon	44·4	1950	144 sq. ft.
2	5" "		solid	2" 5" "	51·0	1720	128·5
3	6" "		solid	2" 6" "	56·24	1536	121·6
4	Ordinary 9" × 4½" × 2½"		solid	2½" 7½" square	57·7	1480	96
5	"Templeboro"		open	2" 3" square and 3½" × 2" oval	36·3	1695	94
6	"Lowcool"		open	2" 5" square and 4" × 3" oval	36·2	1348	93·4
7	"Loftus"		semi-open	3" 3" × 6" rectangle	44·4	1660	88·2
8	Ordinary 9" × 4½" × 3"		solid	3" 7½" square	51·0	1720	88
9	"Mell-Ribenania"		open	2" 3½" square and 5½" × 3½" oval	36·0	1480	77
10	Four leaf		open	2" 7" × 7" leaf and 5" square	57·8	940	66·3
11	Four hole		open	2" 7" square and 4" circular	45·4	1015	60·8
12	"Knicport"		open	2½" 3½" square	33·7	1358	59·6
13	Ordinary 9" × 4½" × 2½"		open	2½" 6½" square	52·4	975	52
14	Ordinary 9" × 4½" × 3"		open	3" 6" square	44·4	1170	48

Note.—Since the figures in the last column are calculated from the plan view only, they are in some cases not strictly accurate.

vestigating the types of clays best suited for use in the manufacture of checker brick. As a result, only selected clays are being used, and the finished product is such that it is well able to meet the most rigid specifications. Brick which is not made for use as checker brick, while it may show a lower first cost, usually proves uneconomical in the long run, due to inefficiency and troubles that may develop during its use.

While some experimental work is being carried out on the use of materials other than fireclay for the regenerator filling, the greatest advances are being made in the development of specially designed checker brick, the purpose of which is to increase the efficiency of the regenerator system through the use of brick shapes that will promote higher gas velocities and turbulence, expose more surface, and more quickly attain thermal equilibrium throughout their mass.

As a result of these studies it has been found that the thickness of the checker brick should be such that it attains a stable thermal condition in one reversal. By experiment it has been found that heat transference into the brick is effective only to a depth of approximately 1 inch. Theoretically, the ideal brick as far as heat transference is concerned should not exceed 2 inches in thickness. In practice, however, it has been found necessary to use a brick of 2.5 inches in thickness, as the 2 inch brick offers considerable danger of over-turning and causing the checker work to fall.

A considerable amount of the heat transfer in the regenerator is due to convection and is impeded to a great extent by the presence of a dead layer of gas next to the brick surfaces. By the use of these specially designed blocks, which in some cases are set to conform with certain geometrical shapes, it is possible to promote high gas velocities and maximum turbulence, both of which will tend to destroy this dead layer and thereby increase the rate of heat transfer. As the rate of heat transfer depends in part on the amount of heating surface exposed to the gases many of these new shapes are more effective than the ordinary type of brick. Table I[1] gives physical data for various types of checker brick. The figures are useful for comparing some of the various brick designs now being manufactured.

[1] R. A. Hacking, "Recent Developments in Open Hearth Furnace Design," J. Soc. Glass Tech. Vol. XVI, No. 63, p. 293, 1932.

SOUTHERN ALKALI DEDICATES NEW PLANT

A two day program, recently officially commemorated the opening of the plant of the Southern Alkali Corporation at Corpus Christi, Texas, thereby placing in operation one of the major industrial developments of the Southwest and one of the largest industrial undertakings projected in the United States within the last four years. The program was arranged by local committees headed by the Chamber of Commerce of Corpus Christi.

Included among the officials of the American Cyanamid Co. and the Pittsburgh Plate Glass Co., joint owners of the Southern Alkali Corp., attending the opening were: —H. A. Galt, President of the Southern Alkali Corp. and Vice President of the Pittsburgh Plate Glass Co., C. M. Brown, Vice President of the Southern Alkali Corp. and Chairman of the Board of the Pittsburgh Plate Glass Co., Harry L. Derby, Vice President of the Southern Alkali Corp. and Vice President of the American Cyanamid Co., K. F. Cooper, Vice President of the Southern Alkali Corp. and Vice President of the American Cyanamid Co., Dr. W. S. Landis, Vice President of the Southern Alkali Corp. and Vice President of the American Cyanamid Co., Raymond Pitcairn, Director of the Southern Alkali Corp. and of the Pittsburgh Plate Glass Co., H. S. Wherrett, President of the Pittsburgh Plate Glass Co., Dr. M. C. Whitaker, Vice President of the American Cyanamid Co., Eli Winkler, K. C. Frazier, Southwestern Sales Manager of the Southern Alkali Corp., T. E. Jackson, Southwestern Representative of the Pittsburgh Plate Glass Co.

Well over four hundred guests gathered in Corpus Christi for the occasion. The first morning an official party of approximately one hundred visited and inspected the newly opened plant, proceeding from there to board the Coast Guard cutter U. S. S. Saranac at the Southern Alkali Corp.'s docks for a trip through the Corpus Christi ship channel to the jetties at Aransas Pass. Lunch was served aboard the U. S. S. Saranac.

The second day's program included an old-fashioned barbecue at world famous Santa Gertrudia Ranch near Kingsville.

TOUGH GLASS BREAKS RULES

An exceedingly tough glass is now being manufactured for use in industrial goggles, spectacles and other uses. In the laboratory these lenses have been dropped from four to ten feet on a concrete floor without breaking. They are not laminated or reinforced by wires or any extraneous means.

While these lenses can and have been broken it is estimated that the blow required is thirteen times that required to break a lense of ordinary glass of the same dimensions. The breaking is also different. Ordinary glass breaks into relatively large, razor-edged splinters, whereas this glass breaks into less hazardous small pieces with rounded edges.

This tough glass is made by violating the traditional "good factory practice" which is considered essential for toughening glass. Glass is usually cooled slowly from the molten condition, to minimize the formation of strain. This process is called annealing.

The process used to make these tough lenses is just the opposite. The glass is heated to the softening point, about 1500°F. and then quickly cooled by an air jet, or immersion in oil at approximately 400°F. The result is that the exterior layer of the glass is quickly solidified, while the interior, cooling at a slower rate, contracts and places compressive forces on the exterior. The interior is placed under very strong opposite but equal tensions which are revealed by polarized light. Instead of avoiding strains as in the old art, strains are intensified, but their direction controlled to obtain symmetrical stresses.

It is quite likely that other uses will be found for tough glass, such as for windshields and windows in automobiles.

KYANITE AS A SOURCE OF ALUMINA

by S. R. Scholes

THREE MINERALS of the composition represented by $Al_2O_3 \cdot SiO_2$ are found in nature—Sillimanite, Andalusite, and Kyanite—distinguished by crystal form and physical properties. Since the identification of mullite, $3\ Al_2O_3\ 2\ SiO_2$, as the stable compound of alumina and silica at high temperatures, these minerals have been sought and exploited as constituents for refractories and ceramic bodies; because each of the three can be converted into mullite and silica with more or less facility by calcination.

Kyanite occurs in North Carolina in deposits of commercial importance. It has been suggested as a constituent of glass-batches, to supply alumina, and deserves consideration because of its high Al_2O_3-content. The pure mineral contains nearly 63 per cent Al_2O_3; samples analyzed in the writer's laboratory show 56 per cent. For purposes of comparison, kyanite may be said to possess three times the alumina-content of feldspar.

The suitability of kyanite for glass-making must be weighed against several requirements. Chief among these are: the availability of an adequate supply of uniform composition; its complete solubility in the melt; a sufficiently low iron-content for the character of the glass to be made.

Uniformity and abundance are matters to be cared for by the purveyors of the material. In these days of chemical control, and of thorough exploitation of mineral deposits before mining and grinding operations are begun, it is altogether likely that the producers of kyanite will be in a strong position with regard to these matters before offering their product to the glass industry.

Trial meltings in this laboratory, using 80-mesh raw kyanite, have shown no undissolved material. The quantity used was sufficient to supply 2 per cent Al_2O_3 in the glass. The fears some have expressed as to the formation of insoluble crystals of mullite seem to be groundless. However, because of the high concentration of alumina in kyanite, it is recommended that 100-mesh material would be preferable on the score of homogeneity.

The iron-content of such samples of kyanite as have come to our attention is much higher than that found in glassmakers' feldspar. In some classes of ware—green or amber bottles, or window glass—this would not be detrimental, but for the production of flint bottles, or even light green, this offers another problem for the producers of kyanite. Selected rock, treated to an intense magnetic treatment, may well furnish a material completely satisfactory in this respect. It must be noted that the quantity of kyanite necessary in a batch would be only one-third that of feldspar for the same addition of alumina and therefore that the tolerable per cent of Fe_2O_3 would be three times as great as with feldspar. That is to say, if a feldspar containing 0.07 per cent Fe_2O_3 is satisfactory in a given glass, the permissible Fe_2O_3-content in kyanite will be 0.21 per cent.

The question of cost is one to be worked out by the glassmaker on the basis of alumina-content, remembering that kyanite presents in addition only silica as a credit against its total cost. For example, kyanite analyzing 56 per cent Al_2O_3 contains 1120 lb. alumina per ton, worth at \$.0288* per lb., \$32.26; also 880 lb. silica, worth as sand \$1.76; total, \$34.02. This represents a competitive price for kyanite (56 per cent Al_2O_3), delivered, against feldspar at \$18.00 per ton.

*Glass Ind., Sept. 1934, p. 174.

MATHIESON'S LAKE CHARLES PLANT READY TO START OPERATIONS

The new \$7,000,000 plant of the Mathieson Alkali Works at Lake Charles, La., will begin operations early in December, it was announced today. Construction work at the new plant is being maintained considerably ahead of schedule, according to company officials, despite the fact that it involves a number of engineering developments embodied in such a plant for the first time.

The Lake Charles plant, it was pointed out, will provide a new source of supply for soda ash, caustic soda and related heavy chemical products over a wide area in the South and Southwest. It will also permit the economical shipment of alkali by water to points on the Atlantic and Pacific seaboards, along the Gulf Coast, and on inland waterways including the Mississippi River and its tributaries.

In addition to rail service via the Southern Pacific, Kansas City Southern or Missouri Pacific and their connections, the plant includes a dock system for loading both barges and ocean-going steamers. These facilities will play an important part in bringing the consumer of alkali and his source of supply closer together from the standpoint of transportation costs.

Since its incorporation in Virginia in 1892 there has been a close relation between The Mathieson Alkali Works and industrial development in the South. For nearly forty years, the Mathieson plant at Saltville, Va., being the only source of alkali in the South, has saved Southern consumers many thousands of dollars in transportation costs each year. With the completion of the new plant at Lake Charles, similar benefits will be extended to an important growing industrial area in the Southwest. The company also operates a third plant at Niagara Falls, N. Y., where caustic soda, anhydrous ammonia, liquid chlorine and chlorine products are produced.

SAND CASE UNSATISFACTORY TO RAILROADS AND SHIPPERS

The recent decision of the Interstate Commerce Commission in the industrial sand case, which has been before it for several years, is neither satisfactory to the shippers and receivers nor to the carriers. The Commission rendered its decision on October 8 and the rates were proscribed to become effective on December 31.

The decision of the Commission, which affects interstate rates only, gives reductions generally but not to the point sought by the shippers. On the other hand, it is understood that the railroads have petitioned the Commission to postpone the effective date of their order because it is impossible for them to prepare tariffs in the alloted time.

Undoubtedly, petitions will be filed from both parties asking the Commission to reconsider the decision as rendered and grant a modification more nearly in line with their respective wishes.

COMMITTEE ON CHEMICAL DURABILITY OF GLASS MAKES REPORT

The Glass Division of the American Ceramic Society is actively engaged in its work relative to tests for chemical durability of glass. The widespread interest, brought about by the need for this work, was demonstrated by the Glass Division's recent and very successful meeting at Lake Keuka.

Stimulus was added by the formation of an International Commission for Glass Technology in Venice last year. J. C. Hostetter, of the Corning Glass Works, was named as the American representative on the commission.

British and German technologists already tentatively have agreed on methods of testing glass for chemical durability. They have asked the Americans to adopt their tentative methods.

A committee on the chemical durability of glass was appointed by James Bailey, chairman of the Glass Division to handle the matter. Those named were: Donald Sharp, chairman; G. W. Morey, U. E. Bowes, W. F. Brown, F. C. Flint, W. C. Taylor and J. C. Hostetter, ex-officio, representing the International Commission for Glass Technology.

The Committee outlined their program and a conference was held on October 8 at the National Bureau of Standards to discuss the problems involved and seek the cooperation of the Bureau. The conference was attended by L. J. Briggs, director, National Bureau of Standards; W. Keith McAfee, president, American Ceramic Society; Donald Sharp, Bailey & Sharp Co.; G. W. Morey, Geophysical Laboratory; W. F. Brown, Libbey-Owens-Ford Glass Co.; J. C. Hostetter, Corning Glass Works and International Commission for Glass Technology; P. H. Bates, G. E. F. Lundell and A. N. Finn, National Bureau of Standards.

It was decided to obtain a large number of samples of sheet glass and hollow glassware from several sources and submit them to the cooperating laboratories for test. The first tests are to be made on crushed, or powdered samples of three types of ware according to definitely prescribed methods to see what uniformity in results is obtained. Then the next step in the program will be considered.

The National Bureau of Standards will be custodian of the samples and will distribute them to the cooperating laboratories at such times and in such quantities as are indicated by the chairman of the committee on durability. The samples will be numbered at the bureau and no reference to their source will be made in any way.

The list of cooperating laboratories is not yet complete, but so far the following organizations have signified their willingness to assist in the work:

Corning Glass Works
Libbey-Owens-Ford Glass Co.
National Bureau of Standards
Hartford-Empire Co.
Owens-Illinois Glass Co.
Bailey & Sharp Co., Inc.
Hazel-Atlas Glass Co.

Other plant and commercial laboratories, also the interested colleges and universities will be asked to lend their aid in this work.

It is hoped that the plans of the committee will finally result not only in standardizing American methods of testing glass for durability but in helping the work of the International Commission and thus lay the groundwork for a truly international method of making tests for durability and a uniform method of expressing results.

VAIL TO GIVE STUDENT LECTURES

In accordance with a long established custom in Philadelphia, Christmas week will afford an opportunity to young people to adventure in the discoveries of science. This year James G. Vail, chemical director and vice president of the Philadelphia Quartz Company will deliver the series of popular lectures. Mr. Vail is the recipient of the 1933 Chemical Industry medal for his work on sodium silicates. He is also the author of the American Chemical Society Monograph, "Soluble Silicates in Industry" and has written and lectured extensively on the subject.

Under the inviting title, "A Grain of Sand", Mr. Vail will cover a wealth of adventures in acquaintance with common things. From the origin of sand beginning with the cooling of the hotter stars, to the application of soluble glasses in many workaday tasks, silica will be traced as a thing of amazing interest and importance. The lecturer has divided his talks into three classifications. The first "A Trip From Hot Stars to Cool Beaches", will give a glimpse of the architecture of crystals, the gem forms of quartz and the elements of which silica is made. The relation of silica and water in geysers, diatoms, and higher plants will develop many points at which this material touches our daily concerns. The second lecture, "Through the Looking-glass" will discuss silica as an essential ingredient of glass, enamel and pottery. Glass making from the ancient beginnings to the most modern developments in special glasses for many new uses, will be shown and described. "Waterglass", the last of the series, covers the material Mr. Vail is so well qualified to expound—silica in fluid form. The unique properties of the various soluble silicates will be demonstrated in such products as fiber boxes, soaps, paper, metal molds, cements, paint, grinding wheels.

All the lectures will be illustrated by numerous exhibits, demonstrations and slides, many of which are original and new. Amazing and beautiful sights will be flashed on the screen by means of polarized light. Through the courtesy of Carl Zeiss, Inc., makers of the Planetarium in the Franklin Institute, a projecting microscope and an epidiascope will be used.

Plate Glass Production Up

The total production of Polished Plate Glass by the member companies of the Plate Glass Manufacturers Association for the month of October, 1934 was 7,512,052 sq. ft., as compared to 6,737,782 sq. ft. produced by the same companies the preceding month, September, and 5,793,693 sq. ft. produced by the Association members in the corresponding month last year, October 1933. This makes a total of 76,830,878 sq. ft. produced by these Companies during the first ten months of 1934, as compared to 75,521,718 sq. ft. produced in the corresponding period of last year.

STATUS OF RESEARCHES ON CURRENTS IN TANKS

By OSCAR KNAPP

German Version in Die Glashutte, Sept. 3, 1934.

THE process of melting glass in pots is old and well understood. Centuries of experience have gained mastery of its problems. But when, thanks to the efforts of Friedrich Siemens, the tank-furnace came into the glass industry, problems arose which were unheard of in pot practice. The huge mass of glass conducted itself strangely as it melted, and many difficulties and defects appeared, easily prevented in pots. The tank produced glass of inferior quality, whose color and clarity and freedom from cords left much to be desired. The great economy of the tank established it in the industry, and called for thorough investigation of the new technique of melting. It was presently recognized that the periodic melting in pots and the continuous process in tanks were different in kind. The sequence is different: in pots the glass is first made, then worked, while in tanks the glass-making and working proceed concurrently. Pots may be individually handled—advanced or delayed in melting. But in tanks we are committed to a regular timing. The movement of the glass in pots is of no concern to us; it occurs in a small volume, and affects a small quantity. But in tanks many movements occur at once, whose control is a severe task, not always successful. With progress in tank-operation, the study of currents has become increasingly important.

The first researcher to publish his observations on the flow of glass in tanks was McSwiney. He showed the dependence of paths and velocities upon tank-design, and the inverse relationship of viscosity and speed. Hot glass moves most rapidly. McSwiney used three methods observing the velocity and course of the streams. One was by watching the islands of batch, or floating pieces of fire-clay; a second was by studying corrosion of blocks. These two sets of phenomena were upset by other causes, so he selected a third, the observation of the glass in a cooled-down tank, in which colored glass had been added at the end of the "fire". He found horizontal stratification, rarely vertical, and the latter seldom deep. The reason for lack of vertical lines of flow was the high viscosity of the deeper glass, when the surface had cooled enough to cause a sinking tendency. Changes of viscosity, such as arise as fresh batch melts, are the chief cause of movement laterally, he concluded.

The prevailing currents in tanks were studied, in practice, by McCauley. In a tank melting Pyrex glass he found cross-currents in the first third (dog-house end). The glass moved to the side-walls at the surface, then sank, and went back toward the center. In the rest of the tank a combination of lateral and lengthwise movement could be established. By throwing in and watching colored bits of cullet he estimated the speed. At temperatures around 1000°C., this reached 4 to 6 meters per hour, while at 1400°C. the colored fragments traveled 9 meters per hour. The method of McCauley has the costly disadvantage of requiring a tank at hand, for the purpose.

Jebsen-Marwedel observed the devitrification in a cooled tank, and concluded that the movement—contrary to that in a boiler—arises from cooling at the side-walls. Here the glass, becoming specifically heavier, sinks downward, and is displaced toward the center and finally upward again, completing a cycle. Thus two curves of flow appear in a cooled tank, elliptical in vertical section. The motion is energetic enough to carry small bits of iron up into the main stream and on into the ware being produced. This thermal current promotes mixing and homogeneity. But when batch is being fed, and glass drawn out, the prevailing movement is forward, involving a comparatively shallow layer. No sharp distinction can be made between these operating—and thermal—movements. The surface stream, according to Jebsen-Marwedel's measurments, may travel 7 to 8 meters per hour.

Stumm has studied the currents in a Fourcault tank, by means of small clay floats, permitting results only as to the surface glass. He found simple movements at the surface, unaffected by the number of machines at work, therefore caused by temperature-differences. The forward motion reached a velocity of 5 to 6 meters per hour. The cooling effect of the side-walls caused lateral currents, and in certain locations, as behind the bridge-wall and near idle machines, there were quiet spots.

König confirmed the results of Stumm, and has observed velocities of 12 meters per hour. He concludes from these speeds that more glass flows forward on the surface than is being drawn out in the same time. Therefore a counter-current, beneath, must occur, athough this cannot be directly observed. Proximate reckonings indicate that more than 90 per cent of the moving glass must return toward the filling end, and only 5 to 10 per cent pass on to be worked. This same motion occurs in the idle tank, and is attributed to the difference in temperature between melting and working-ends. Lateral movement, he finds, is limited. The stream flows from hot to cold areas. It can be set up in both directions and toward the sides, by making the center of the tank hotter than either end.

Wuromus and Guss based observations on the travel of raw batch and of a loose floater, in a window-glass tank. Batch charged from the side took up a circulating path, ending in a spiral in the center.

Transverse currents are attributed by Jochim to poor firing, whereby a low temperature at one end of the flame causes a cooler wall. The batch migrates toward this wall, and this travel may not be laid to the driving force of the flame, because it sometimes proceeds against the flame. An evil effect of this transverse current is attack on the blocks, causing bad glass.

Currents in a tank having bridge-wall and throat have been studied by Gehlhoff, Schneekloth and Thomas, both in working and idle states. In the working-chamber, at rest, the stream flows from bridge-wall to outer-walls, at the slow rate of one meter per hour. They determined surface temperatures, and found a source of currents in the hottest area, from which the glass flowed in all directions toward cooler zones. The movement is deeper

than hitherto recognized, and involves the whole mass of glass, which has not been found true in Fourcault tanks. These currents are held to be important as promoting mixing.

Bowmaker and Canwood added Ba O to a baryta-free glass and determined by analysis when Ba O first appeared in the ware, which occurred 9 hours after the first addition. This shows powerful currents, for the baryta first appeared, not at the machine drawing most glass, but at the one nearest the center-line. Bowmaker postulates two symmetrical, spiral streams, drawing toward both side-walls. Hampton made similar trials, and found that the last of the Ba O required seven weeks in escaping from the tank.

Marden introduced cobalt into a small tank supplying a Danner machine, and then cooled the unit as rapidly as possible as soon as the color appeared at the machine. There was little mixing. In this small tank, the blue glass had flowed in a thin stream near the bottom to the working end, where it rose to the surface. Thus in certain cases the drawing-stream may prevail.

Hausner examined the findings of Gehlhoff, and showed that the hot-spot theory does not hold for a tank with horse-shoe flame (stirnbrennerwanne).

Hausner pictures three streams, one on the surface toward the drawing-end, a reverse current (deeper) in the direction of the charging, and another stream, at the bottom, toward the drawing-end. He advises a temperature-maximum apart from the charging location, but not far enough away to cause a reverse current on the surface.

Since observations on operating tanks can give no complete view, several workers have turned to small models, and viscous liquids of glass-like behavior. Dyes are added, and surface-heating applied, to stimulate actual conditions on a tiny scale. Schild has thus verified the conclusions of Gehlhoff for bridge-wall constructions. He could not repeat the findings of Hausner for tanks with floaters.

Strume and others found results in model tanks similar to those already cited—currents set up from the hotter parts of the surface toward cooler zones.

The model by Flint and Lyle had metal walls with glass windows. Colored water filled the tank at first, then clear water was added while the excess was drawn off. In 16 hours the tank contained only colorless water, except for the corners and a shallow bottom-layer. When clear, warm water was poured into a tank-full of colored water, and the bridge-wall was cooled, the colored water was driven from the surface directly to the bridge, through the throat, to the working-end. If the bridge-wall were not cooled, several super-imposed reverse currents were set up, only the deepest one escaping through the throat. When castor oil was added, it remained as a viscous bottom-layer, with a cordy admixture in the throat. When the surafce was heated by an incandescent lamp, a swirling current was set up, from the source of heat toward the bridge. In the opinion of these observers, the current in the tank in operation flows directly from the charging-point to the throat.

Thus there arise among careful experimenters conflicting opinions, and up to now there is no certain knowledge of the flow of glass in tanks. The reasons lie in the difficulty of the problem, and also in the variety of construction and operation of the tanks observed. Much more work is required, before accurate and helpful information shall be acquired.

CERAMIC CONVENTION PLANS PROGRESS

Plans are rapidly taking shape for the 1935 convention of the American Ceramic Society to be held in Buffalo, N. Y. February 17 to 23 and developments point to one of the most important and enjoyable gatherings of the society in recent years. Headquarters of the convention will be the Hotel Statler where all sessions will be held.

The committee is planning to hold in connection with the meeting an exhibit of "Made in New York State" ceramic products, together with a series of educational process exhibits. It is expected that these will be of general interest to the public as well as the ceramists.

The formal opening of the meeting is arranged for Sunday evening, February 17. It will take the form of a reception and a concert to be given by a nationally recognized radio musical organization. Details of the concert feature will be announced later.

On the following day, Monday, the technical and business sessions of the organization will be started with meetings both in the morning and afternoon. Monday night there is to be a surprise party, the details of which the entertainment committee is guarding with much secrecy. The title of the affair, "The Shuffle", is about all that is being divulged at the present time.

The annual ball is scheduled for Wednesday night. One of Buffalo's best dance orchestras will furnish the music and there will be a most entertaining floor show. The plant visitation committee has arranged a fine schedule which will include visits to many industrial places of interest in Buffalo, Rochester and Niagara Falls.

Women visitors are to be well entertained with bridge parties, teas, dances, receptions and a trip to historical old Fort Niagara. A day will be spent at Niagara Falls, the special feature of the trip being the magnificent snow and ice scenery which usually glorifies the cataracts during the winter months. Arrangements are also being made for a special illumination of the Falls during the visit of the ceramists.

The Executive Committee of the Convention is as follows: Dean M. E. Holmes, Alfred University, Alfred, N. Y.—Chairman; S. F. Walton, The Exolon Company—Vice-Chairman; L. D. Walrath, Vice-President, Acme Shale Co.—Treasurer; J. Easter, The Carborundum Company—Secretary; Dr. J. C. Hostetter, Director of Research, Corning Glass Works—Member Ex Officio.

Committee Heads include; L. D. Walrath—Finance; F. D. Bowman, The Carborundum Company—Publicity; D. E. Sharp, President, Bailey and Sharp Co.—Transportation; Dr. R. C. Benner, Director of Research, The Carborundum Company—Plant Trips; Fred Hazelwood, Asst. General Manager, Buffalo Pottery-Ladies Entertainment; Dean M. E. Holmes, Alfred University—Exhibits; S. F. Walton, The Exolon Company—Entertainment; G. S. Diamond, Vice-President, Electro Refractories—Cooperative and Meeting Service.

EQUIPMENT AND SUPPLIES

AUTOMATIC TANK PRESSURE CONTROL

An automatic furnace pressure control has recently been developed by Leeds & Northrup Company, Philadelphia, Pa. Its function is to control the pressure and damper adjustments on glass melting tanks so the operator can concentrate on his other duties and to reduce the losses due to wasteful operation.

This pressure control is quite simple and consists of but three principal devices—a pressure controller, an electrical relay and a motor operated damper drive. Through a short pipe, variations in tank pressure are transmitted to a bell in the controller. Increase in pressure pushes the bell upward, decrease lets it down. This movement tilts a balanced beam which carries electrical contacts. When it tilts either way it closes electrical contacts and energizes an electrical relay.

The relay instantly energizes the motor drive adjusting the damper to increase or decrease the effective opening of the stack. The resultant change in draft returns the furnace pressure to the control point, pressure on the bell is corrected, the beam comes back to balance, the electrical contact opens and the motor stops. The control system is at rest but remains instantly responsive to the next change in pressure.

HIGH-SPEED GAS-ELECTRIC TRUCK

A high-speed truck of powerful construction has been brought out by The Elwell-Parker Electric Company, Cleveland, O., to encourage further expansion of its pallet system of materials handling. It will help to make pallets feasible for many concerns that have not heretofore used that method of materials-handling, tiering, storing, and removing from storage.

The new machine is heavily powered and will handle loads on steep ramps at high speeds. A transmission safety-lock is fitted to hold the truck on the ramp should it be necessary to stop, while acceleration from a stop on an incline is attained by the standard Ellwell-Parker method.

The truck, a gas-electric unit, responds quickly to the demands of the operator and sets an advanced standard for safety, speed and heavy duty service. It is exceptionally powerful on ramps and speedy on the straightaway over long distances.

Its design provides for the use of a ram, two or more forks and other accessory attachments that enable it to handle a load on the pallet or skid ahead of the machine. Large crates and rolls can be picked off the floor, transported in tilted position and stacked without the operator leaving his position. The truck has a rated capacity of 4000 to 7000 pounds and a travel speed of 6 to 12 miles an hour.

TANK ROOF TEMPERATURE CONTROL

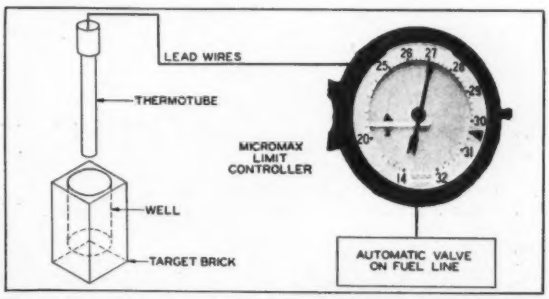
A temperature-limit control for tank roofs has been developed by the Leeds & Northrup Company, Philadelphia, Pa. This device gives protection against excessive roof temperatures of glass melting tanks practically eliminating the dripping roof and increasing the life of tank roofs. It removes the uncertainty of manual control, detecting each variation of temperature—indicating it clearly—acting instantly if the temperature becomes unsafe. It keeps the roof temperature below the danger line always.

The temperature-limit control device consists of only four units and its principle is like the simple "burning glass", used to focus the sun's rays. A carborundum block with a well drilled in it is inserted in the roof. The thermotube is mounted above the block and outside the furnace. A steel reflector in the thermotube focuses light and heat from the bottom of the block and the rays are reflected on a thermocouple inserted in the thermotube. The thermocouple heats, generating an e.m.f. proportional to the roof temperature which is registered on a Micromax Round Chart Recorder which is in plain view of the operator at all times. Through an automatic valve in the fuel line it reduces automatically the fuel, reducing the roof temperature.

This control requires only a small maintenance expense which is due principally to the fact that there is no thermocouple in the furnace. There is no danger of burning out a "couple" when the roof is the hottest and protection is needed most. There is no need to stop to replace a thermocouple. Taking the "couple" out of the hot furnace cancels the need for a complicated cooling system. The additional expense involved in replacing platinum thermocouples is also saved.

The "couple" in the thermotube is subject to only negligible heating—hardly 1/10 of the temperature it is capable of withstanding. It lasts for years without repairs or replacement.

By the use of the temperature control the life of the roof is prolonged and the tank can be run right up to the highest safe temperature continuously.



These four primary units of the control employ the simple "burning glass" principle, used to focus the sun's rays.

SMALL PYROMETER

A small pyrometer for use with furnaces, small diesel engines, gas engines, batteries, etc., has recently been developed by the Thwing Instrument Company, Philadelphia, Pa. It is calibrated in two standard temperature ranges—80°F to 1200°F and 80°F to 2400°F. They are furnished in two styles: one for indicating temperatures at a central point, from several sources; the other, for indicating temperature from only one source.

BIBLIOGRAPHY OF ALUMINA AND FELDSPAR IN TRANSPARENT GLASS (1918 to 1933)

Compiled by Waring Bradley and Donald E. Sharp*

for **THE FELDSPAR ASSOCIATION**

(*Continued from November Issue*)

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(*Concluded*)

CATALOGS RECEIVED

Polarizing Microscopes, issued by Bausch & Lomb Optical Company, Rochester, N. Y., describes various types of this instrument. It is no longer confined to petrography, but is now used extensively in the field of chemical microscopy and in other fields. *Something New in Spectographs*, describing a small quartz spectograph much needed instrument for industry and education. *The New Density Comparator*, for rapid quantitative spectograph analysis. The density lines on the photographic spectrum plate are measured by photo-electric means and the result read directly from a scale.

Temperature-Limit Control for Furnace Roofs. Application Bulletin No. 53-116 issued by the Leeds and Northrup Company, Philadelphia, Pa., explains simply and interestingly a new method for protecting furnace roofs from over-heating.

ADDITION TO PLANT

The Eclipse Glass Company, Thomaston, Conn., has just completed a one story brick building 50 x 125 feet which will be used for the silvering and beveling of flat glass.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

		Carlots	Less Carlots
Acid			
Citric (dom.)	lb.	...	.29
Hydrochloric (HCl) 20° tanks	Per 100 lb.	...	1.10
Hydrofluoric (HF) 60% (lead carboy)	lb.	...	.13½
52% and 48%	lb.	.10	.10-.11½
Nitric (HNO_3) 130 lb. carboy ext. Per 100 lb.		5.50	...
Sulphuric (H_2SO_4) 66° tank cars	ton	15.50	...
Tartaric	lb.	... { Po. or Gr. Cry.	.25 .25½
Alcohol, denatured	gal.	...	...
Aluminum hydrate ($Al(OH)_3$)	lb.	.04-.04½	.04½-.05
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Ammonium bicarbonate (f.o.b. works)	lb.	.05¼	...
(f.o.b. N. Y.)	lb.	...	.0571
Ammonium bifluoride (NH_4FHF)	lb.	...	.15
Ammonium nitrate (NH_4NO_3)	lb.	...	.08
Ammonia water (NH_4OH) 26° drums	lb.	...	.02¾
Antimonate of Sodium	lb.	...	.10½
Antimony oxide (Sb_2O_3)	lb.	...	.10-.13-.14
Antimony sulphide (Sb_2S_3)	lb.	...	.08
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03½	.04
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	40.00	45.00
90% through 100 mesh	ton	37.00	...
Barium hydrate ($Ba(OH)_2$)	lb.	.05	.05½
Barium nitrate ($Ba(NO_3)_2$)	lb.	...	.08½
Barium selenite ($BaSeO_3$)	lb.	...	1.50-1.75
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Bone ash	lb.	.06	.06½
Borax ($Na_2B_4O_7 10H_2O$)	lb.	...	...
Granulated	In bags, lb.	.02	.02¼-.02½
Powdered	In bags, lb.	.02¼	.02½-.02¾
Boric acid (H_3BO_3) granulated	In bags, lb.	.04¼	.04½-.04¾
Cadmium sulphide (CdS)—	lb.	...	.70-.75
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	...	...
Chromite	lb.	...	.0215
Cerium hydrate 100 lb. drums and 600 lb. barrels	lb.	...	.65
Chrome Oxide Green, 400 lb. bbls.	lb.	...	.215-.25
Cobalt oxide (Co_3O_4)			
In bbls	lb	...	1.25
In 10 lb. tins	lb.	...	1.35
Copper oxide			
Red (Cu_2O)	lb.	...	.25
Black (CuO)	lb.	...	.17-.19
Black prepared	lb.	...	.22
Cryolite (Na_3Al F_6) Natural Greenland (Kryolith)	lb.	.08½	.09
Synthetic (Artificial)	lb.	.085	.09
Epsom salts ($MgSO_4$) (imported) technical	Per 100 lb.	...	2.30
Feldspar—			
20 mesh	ton	10.00-12.25	
40 mesh	ton	10.50-12.75	
Granular	ton	10.75-13.00	
Semi-granular	ton	10.00-12.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	32.00	...
In bags	ton	33.60	38.00-40.60
Formaldehyde, bbls.	lb.	...	.07
Graphite (C)	lb.	...	.04-.07
Iron oxide—			
Red (Fe_2O_3)	lb.	...	.0425
Black ($Fe3O_4$)	lb.	.04½	..
Iron chromate	lb.	...	.035-.05
Kaolin (f. o. b. mine)	ton	8.00-9.00	..
English, lump, f. o. b. New York	ton	14.50-25.00	24.50-30.00
Kryolith (see Cryolite)			
Lead chromate ($PbCrO_4$)	lb.	...	.16
Lead oxide (Pb_3O_4) (red lead)	lb.	.06	...
In 5 Ton lots	lb.	...	.065
Less than 5 Tons	lb.	...	.07
Lepidolite	ton	45.00	...
Litharge (PbO)	lb.	.05	...
In 5 Ton lots	lb.	...	.055
Less than 5 Tons	lb.	...	.06
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	...
Burnt (CaO) ground, in bulk	ton	7.00	..
Burnt, ground, in paper sacks	ton	9.00	
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.25	2.25
Limestone ($CaCO_3$)	ton	1.75-2.50	...
Magnesium carbonate ($MgCO_3$)	lb.	.06	.08-.09
Magnesium sulphate (U.S.P.)	lb.	...	.03
Manganese, Black Oxide			
In Paper bags	ton	45.00	50.00
In Burlap bags	ton	46.50	51.50
In Casks	ton	48.00	53.00
Neodymidm oxalate, 50 lb. drums	lb.	...	5.00
Nickel oxide (Ni_2O_3), black	lb.	...	.35-.40
Nickel monoxide (NiO), green	lb.	...	.35-.40
Plaster of Paris, bags	ton	31.00	23.00-29.00
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	...	.08⅝
Powdered	lb.	...	.09⅛
Potassium carbonate	lb.	.0825	.0875
Calcined (K_2CO_3) 96-98%	lb.	.07⅞	.0875
Hydrated 80-85%	lb.	.07¼	.0775
Potassium chromate (K_2CrO_4) 450 lb. bbls.	lb.	...	.16
Potassium hydrate (KOH) (caustic potash)	lb.	.06¼-.06½	.08-.08½
Potassium nitrate (KNO_3) (gran.)	lb.	...	.06-.06¼
Potassium permanganate ($KMnO_4$)	lb.	...	.19
Powder blue	lb.	...	.17-.18
Rare earth hydrate			
100 lb. drums	lb.	...	.35
325 lb. barrels	lb.	...	.30
Rochelle salts, bbls.	lb.	...	.12½
Rouge	lb.	... { Po. or Gr. Cry.	.13½
Rutile (TiO_2) powdered, 95%	lb.	.15-.20	.20-.25
Salt cake, glassmakers (Na_2SO_4)	ton	18.00	27.00
Selenium (Se)	lb.	...	2.00-2.10
Silver nitrate ($AgNO_3$) . (100 oz. bot.)	per oz.	...	.40¼
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	1.10	...
In barrels	Per 100 lb.	1.50	...
In bags	Per 100 lb.	1.25	
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06⅛	.06⅜
Sodium chromate ($Na_2CrO_4 10H_2O$)	lb.	...	.08
Sodium fluosilicate (Na_2SiF_6)	lb.	.05	.05¼
Sodium hydrate ($NaOH$) (caustic soda)			
Flake	Per 100 lb.	3.00	...
Solid	Per 100 lb.	2.60	
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls.	Per 100 lb.	...	2.00-2.25
95% and 97%			
Bulk	Per 100 lb.	1.175	...
200 lb bags		1.24	1.29
100 lb. bags		1.275	1.325
Sodium selenite (Na_2SeO_3)	lb.	..	1.80-2.00
Sodium uranate (Na_2UO_4) Orange	lb.		1.50-1.55
Yellow	lb.	...	1.50-1.55
Sodium uranyl carbonate	lb.	...	.80-.90
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.45	3.70-4.10
Flowers, in bags	Per 100 lb.	3.10	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25
Tin chloride ($SnCl_2$) (crystals) . in bbls.	lb.	...	.38
Tin oxide (SnO_2) in bbls.	lb.	...	.54-.58
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	...	3.00
Yellow orange	lb.	...	1.60
Zinc oxide (ZnO)			
American process, Bags	lb.	.065	.0675
White Seal, 150 lb. bbls.	lb.	.10⅝	.10⅞
Green Seal bags	lb.	.09⅜	.09⅝
Red Seal, bags	lb.	.08⅜	.08⅝
Zircon			
Granular (Milled .005-.02c higher)		.07	.67½-.08
Crude. Gran. (Milled .005-.02c higher)		.03½	.04 .05

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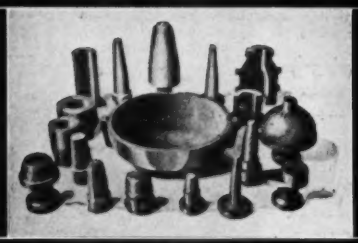

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